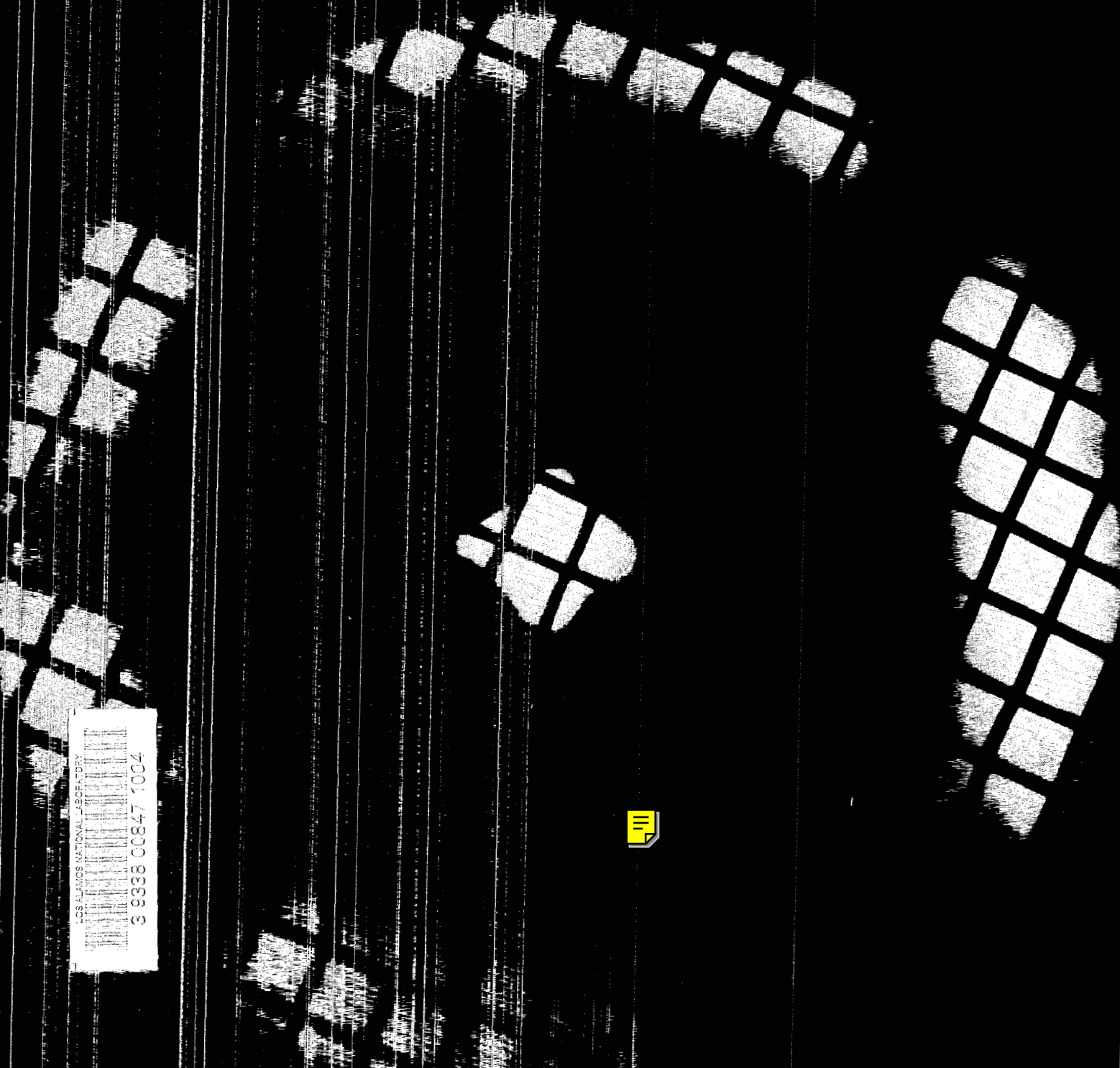


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*ON THE COVER:* Sparks illuminate the vanes during the successful test of the RFQ device. Photo by Henry Ortega. *AT LEFT:* Launching track for vehicles leaving the moon would use less energy to attain escape velocity than would a vertical rocket takeoff. Illustration by Krafft Ehrlicke. (See story on p. 28.)

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## RFQ IS ALIVE AND WELL...

**The combined requirements of continuous duty, high current and high reliability posed a unique challenge to accelerator researchers.**

**By JOHN T. AHEARNE**

One of the telegrams sent during the jubilant hours after the extraordinarily successful Valentine's Day inaugural test of the radio-frequency quadrupole (RFQ) was to I.M. Kapchinskii at the U.S.S.R.'s Institute for Theoretical and Experimental Physics in Moscow. It simply stated, "The RFQ is alive and well at the Los Alamos Scientific Laboratory."

Eight years earlier, Kapchinskii had outlined a theory which described a linear accelerator system capable of focusing and accelerating low velocity subatomic particles with virtually no loss of particles from the beam. The concept was so revolutionary that, when it resurfaced at a LASL workshop in 1977, it was met with considerable skepticism.

The theory found its way to Los Alamos via J.J. Manca, a Russian-educated Czech who years earlier had emigrated to Canada and, in 1977, was a two-year visiting staff member working here on means to accelerate particles at low velocities.

In October of that year, Bob Jameson (now with the Accelerator Technology Division) organized a workshop to address the questions of beam quality—particle loss and the unwanted spreading of the beam in accelerators.

Jameson asked Manca to present a paper at the workshop concerning his persistent notion that nearly complete particle capture at low velocities was possible—an idea that many felt was a

misinterpretation perhaps caused by translation difficulties.

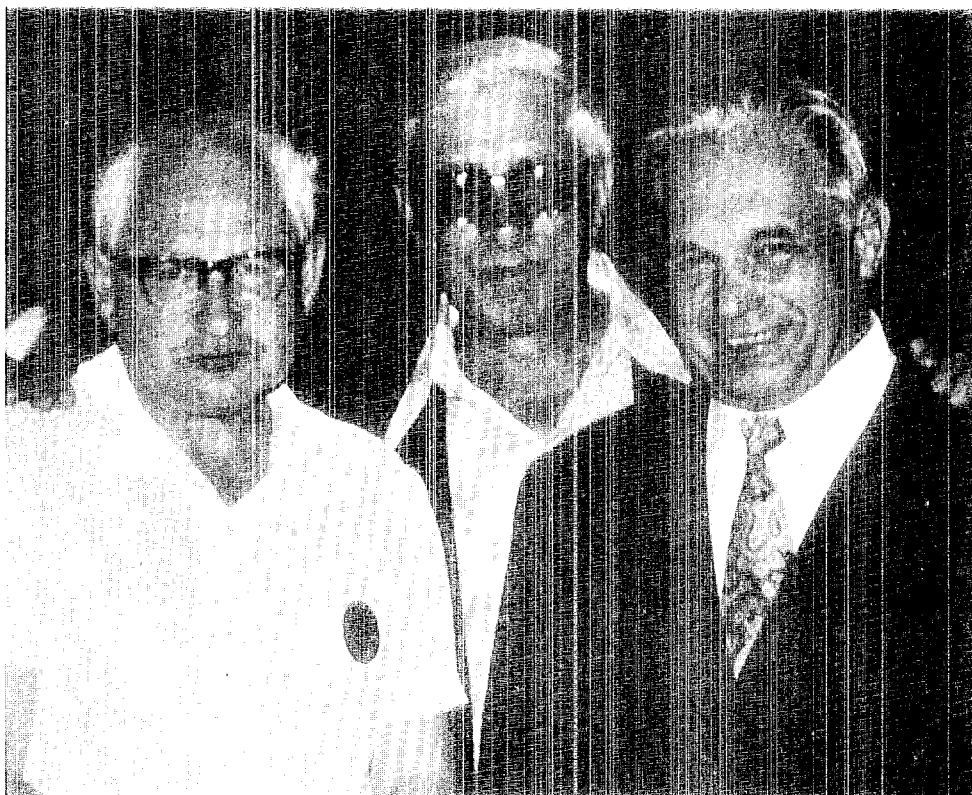
Manca repeated the same "astounding" statements in his presentation, writing, "The injection energy can be as low as 50 keV and the capture coefficient remains close to 100 percent." (The injection energy required to initiate the beam at LAMPF is 750 keV.)

"Because the concept was just what we were looking for, and because Manca was so persistent, we initiated a literature search and the Kapchinskii paper was the first analytical description we found," Jameson said.

The LASL researchers discovered the paper in German, translated from Russian, and Jameson asked A.D. Cernicek to alleviate any possible language misinterpretations. Cernicek, an ISD-4 translator, teaches German and Russian at Los Alamos High School.

The translator's efforts showed that Manca was correct in his interpretation of the literature. The formulas in the Kapchinskii paper were quickly analyzed, and excitement for the new concept began to grow.

A team of LASL experts on accelerator structure development began to consider ways to turn the theory into reality. The group included Ed Knapp, now AT Division Leader, and AT-1 Group Leader Don Swenson. (AT Division was formed in January of 1978.) The pair studied the theory, drew pencil sketches of their mental pictures of the structures, and



*Eight years ago, I.M. Kapchinskii (left) outlined a revolutionary theory for a linear accelerator. Later, V.A. Teplyakov (right), a co-inventor with Kapchinskii, reported on an experimental device. (Colleague Andreev in center)*

eventually came up with a plastic model they could use as a visual aid in explaining the structure to others.

Then in February of 1978, LASL was asked, by the Office of Fusion Research, Office of Energy Research at DOE, to design and build an accelerator, for Hanford's Fusion Materials Irradiation Test (FMIT) facility, capable of producing an intense and high quality beam. The particle accelerator necessary for the FMIT "neutron factory" would require significant advances beyond the state-of-the-art technology of the time. The accelerator would have a 10- to 20-year useful operating life. Its output would be 0.1 amperes, which is a billion-billion particles a second.

Because most of today's high-current accelerators operate only in a pulsed mode and produce 10 to 100 times less current, the FMIT's combined requirements of continuous duty, high current, and high reliability posed a unique challenge to LASL's Accelerator Technology Division. Totally new accelerator techniques would have to be developed for the FMIT. There at the right place and the right time was the RFQ. The highly reliable RFQ would meet these requirements economically and efficiently (see accompanying story).

Two factors were primarily responsible for the FMIT sponsor's eventual acceptance of the RFQ theory as the avenue toward meeting the requirements at Hanford. First was the realization that meeting the FMIT needs in the old ways

would present immense technical and engineering difficulties. Second was the dwindling of scientific skepticism in the accelerator community after the AT researchers held a spring 1978 workshop to explain the promise and potential of the new structure. The go-ahead was given to design and build the RFQ for Hanford.

Three general steps would have to be accomplished before the first test. First, a complete understanding of the theory by the team was necessary. Swenson and Knapp had developed a general understanding of the theory—they were the ones who had a feel for the structure. With their physical descriptions and models, they began to help others understand, and moved the team toward the second necessary step to fruition—to develop computer codes to simulate how particles would move through such a structure.

Dick Stokes, who had worked on accelerator structures at the Van de Graaff, came from P-Division to guide the overall program and develop the theory in more detail. Beam dynamicist Ken Crandall, and later Bruce Chidley from Canada's Chalk River National Laboratory, began creating "some pretty fancy codes" to describe the future RFQ. Tom Wangler came from Argonne to help with theory and design.

Gary Rodenz of AT-4 bridged the gap between the second and third steps along the experimental path by using the computer codes in the actual designing

of the first RFQ. Jim Potter, an expert on radio-frequency cavities and accelerator structures, was to be the man who "put the metal together."

The hardware part of the experiment had to be completely done from scratch. AT researchers made repeated requests to visit V.A. Teplyakov at the Serpukov Institute for High Energy Physics, U.S.S.R., who was a co-inventor with Kapchinskii and had reported in the literature on an experimental device. They hoped to see what sort of hardware approach the inventors had taken. (Ed Knapp did have the opportunity to discuss the theory with Kapchinskii.) Despite two years of effort, permission for the trip was never received from the Soviets, and it is not known for sure whether an RFQ structure was ever built in the U.S.S.R.

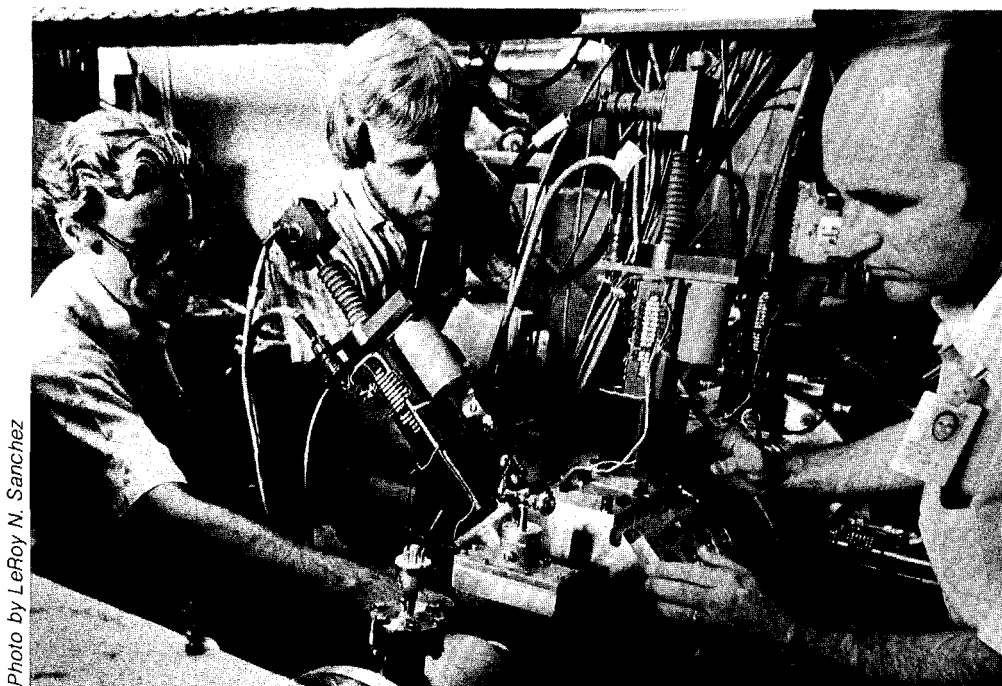
Potter, aided by Fred Humphry, made a number of sheet-metal models and tuned them in his laboratory, developing procedures to achieve the required field distributions in the structure, and working out a method to provide radio-frequency power. In parallel with Potter's activities, Hanford's Steve Williams made a high power test section to investigate how much voltage could be applied to the vanes before sparking between them occurred. Potter and Williams also began to develop more computer codes for the most vital step in producing the first proof-of-principle RFQ—the delicate and precise job of cutting the vanes in LASL's Shops Department (SD).

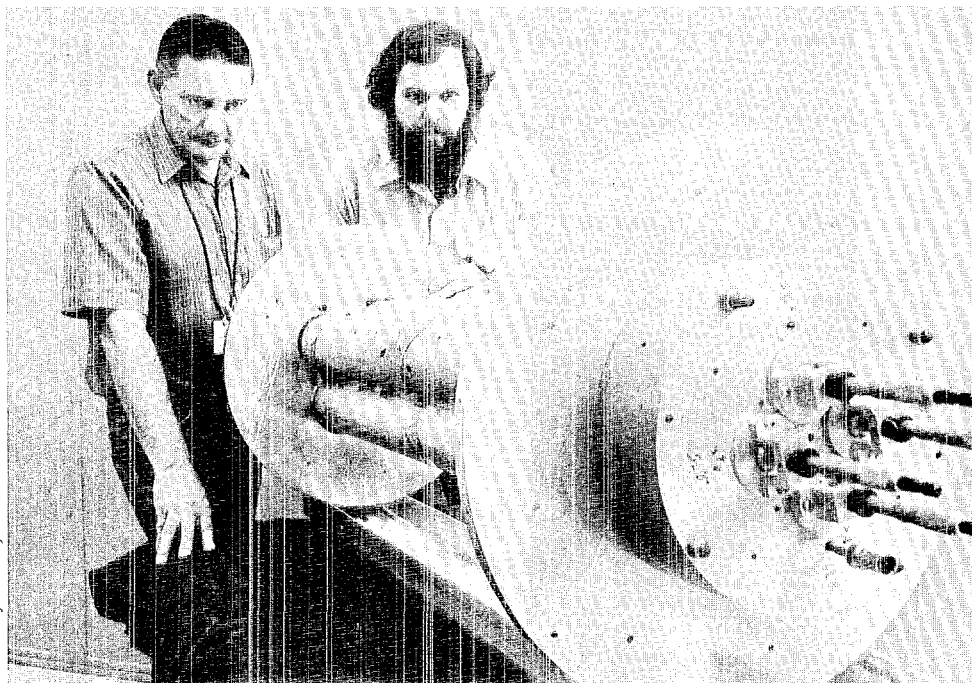
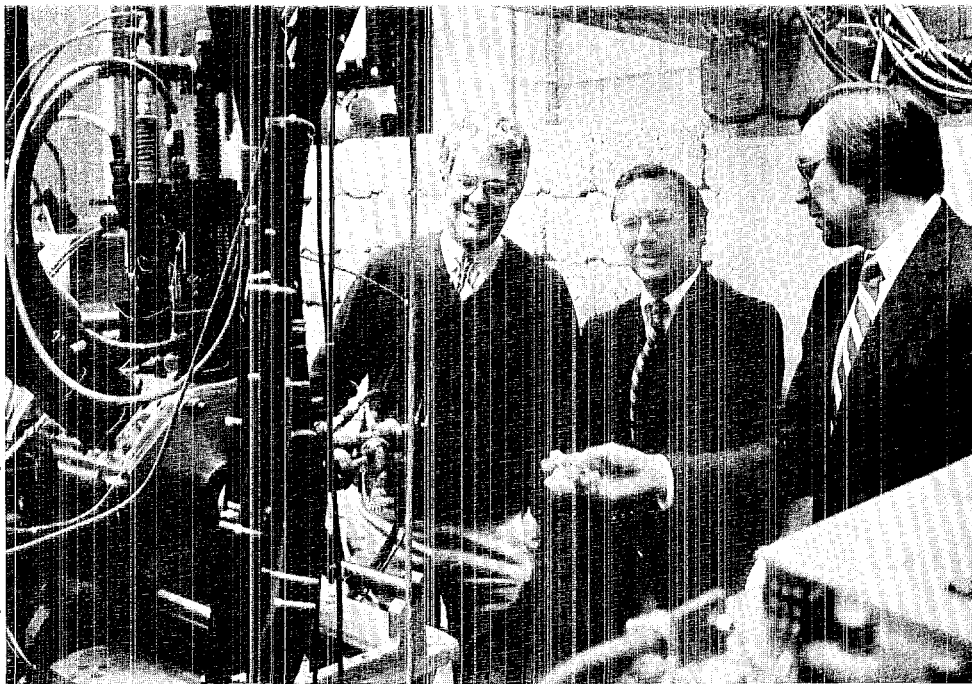
AT scientists agree that the RFQ development would have been impossible without SD, headed by Joseph F.B. Szoo, and its one-of-a-kind numerical milling machine. The machine, programmed and monitored by SD experts, is capable of milling metal to precise tolerances as described by mathematical formulas. At least three dozen machinists and technicians were involved in the RFQ work; the main job of cutting the vanes was done in Shop 13 of SD-1, headed by Ed Riggs with supervisor Leroy Wampler. Working closely with Potter and Williams on the milling machine programs was Otto Maier of SD-DO. Given that the waves and scallops on the vanes of the RFQ must conform to the movement of particles through electrical fields alternating at 425 million cycles a second, the accomplishment of such precision is, in itself, a remarkable machining feat.

Long-time mechanical engineer Chuck Fuller, AT-4, began the assembly for the first RFQ test. For the experiment with the real beam, sheet metal assemblies had to be replaced with a carefully engineered structure. Fuller, whose accelerator engineering experience began at PHERMEX, had to insure that the final precision required was achieved after all the parts were assembled.

Final assembly began in the fall of 1979 in Jim Stovall's PIGMI laboratory. Under overall proof-of-principle coordinator Milt Machalek, an AT-1 / AT-4 team readied the hardware for the final

**TOP:** Chuck Fuller displays an engineering design model. The plastic model is a full-scale quarter section model of the RFQ for Hanford's Fusion Materials Irradiation Test facility. The circular structure behind him is part of the drift tube accelerator. **BOTTOM:** (Left to right) Jim Stovall, Steve Williams and Milt Machalek examine the experimental RFQ in the PIGMI lab.





TOP: AT Division Leader Ed Knapp and Laboratory Director Don Kerr proudly show off the RFQ to the President of Westinghouse Hanford Co., John Yasinsky. BOTTOM: AT researchers, Arlo Thomas (left) and Jim Potter, check out a cloverleaf model of an RFQ whose outer jacket has been removed.

**The missing link in linear accelerator development is progressing quickly from theory, to experimental device, to application.**

*Two of the RFQ vanes are displayed by Shop 13 machinists (left to right) Alex Lopez, George Zakar and Ed Andolsek. Photo by Bob Peña*



phase of the experiment. Bob Hamm reconfigured the injector systems he had helped build for PIGMI to provide the proper input beam for the RFQ. Hamm, Crandall and Kim Melson laid out the input and output beam transfer systems. Jim Stovall, Dave Chamberlin, Brian Smith and their crews readied the beam transport lines, vacuum and beam diagnostic systems necessary to verify the RFQ performance. An SD team working with P Division, including Ray

Squires and Donald Marien, machined most of the remaining RFQ parts, guided assembly, and made a tuning jig to precisely adjust the equipment.

In mid-February, 1980, everything was ready. The structure itself provided the drama for the initial run. As the radio-frequency current was turned on low, the device began sparking across the vanes—an expected and undesirable occurrence. When sparking occurs, researchers must wait until the structure



*Dick Stokes, Bob Jameson, Tom Wangler and Don Swenson reminisce about the days when the RFQ was just a preliminary conceptual model.  
Photo by LeRoy N. Sanchez*

becomes "accustomed" to the current and stops sparking. Then they add more power until it sparks again. The question was whether the desired power could be reached with no sparking. Power was reached. They turned on the beam. The device, representing more than two years of work by dozens of scientists, engineers, technicians and machinists, operated immediately and perfectly.

With the success, and while testing continues, LASL scientists can now

speculate more on the potential of the RFQ. Because of its simplicity and economy, the RFQ promises to be an important development in the evolution of particle accelerators for medical applications (to produce neutrons for cancer therapy or pi-mesons for pion therapy in a hospital environment), in the generation of research accelerators, and in the practical application of accelerator technology to fields such as heavy ion driven fusion.

Don Swenson called the radio-frequency quadrupole (RFQ) "revolutionary" and the "missing link" in linear accelerator (linac) technology.

The initial tests on the RFQ represented a giant step forward in this technology because of its ability to accelerate subatomic particles and to focus them into a coherent beam using a powerful radio-frequency electrical field.

Linacs, such as LAMPF, are primarily research devices that are used as an artificial source of well-defined beams of subatomic particles for studies in nuclear science. In most linacs today, the focusing of the beam—keeping it in a tight, compact line—is done with magnetic fields. However, magnetic focusing is "velocity dependent." That is, the slower the particles in the beam are traveling, the stronger the magnetic field is required to counteract the disruptive effects of the electrical fields. At the low particle velocities required at the beginning of practical linacs, it is not possible to build strong enough magnets in the available space.

Therefore, in machines to date, the particles have to be raised to a higher velocity where magnetic focusing is possible. This is done using large power supplies, such as the 750 keV required at LAMPF, which are complex and costly. The RFQ, using only electrical fields, can focus the beam without regard to particle velocity, thereby having the ability to capture lower energy (slower) particles, and essentially eliminating the need for large and costly power supplies.

The RFQ also has an inherent capability of performing another vital operation, called "bunching," as the beam is being focused and prepared for entry into the main section of the linac. (This main section, which uses a different kind of accelerator structure and could be hundreds of meters long, is where particles are accelerated to the final velocities necessary for experiments or applications.)

The linac accelerates the particles by taking advantage of the principle of opposite charges attracting and like charges repelling. The electrical field that accelerates the particles is cyclical—that is, it changes from a positive to a negative orientation many times a second. The charged particles in the beam, therefore, must be ordered and arranged into sequential ball-shaped "bunches" so they enter the linac during the half cycle when the electrical field is charged to accept them. With present systems, the bunches are not well

formed; they tend to have long tails. The particles in the tails tend not to be accelerated properly in the main section of the linac, often resulting in particle loss and degradation of beam quality. The RFQ, whose sophisticated design allows bunching with no tail formation, little degradation of beam quality and little particle loss, will provide a highly efficient and reliable link between the particle sources and the acceleration section of future linacs.

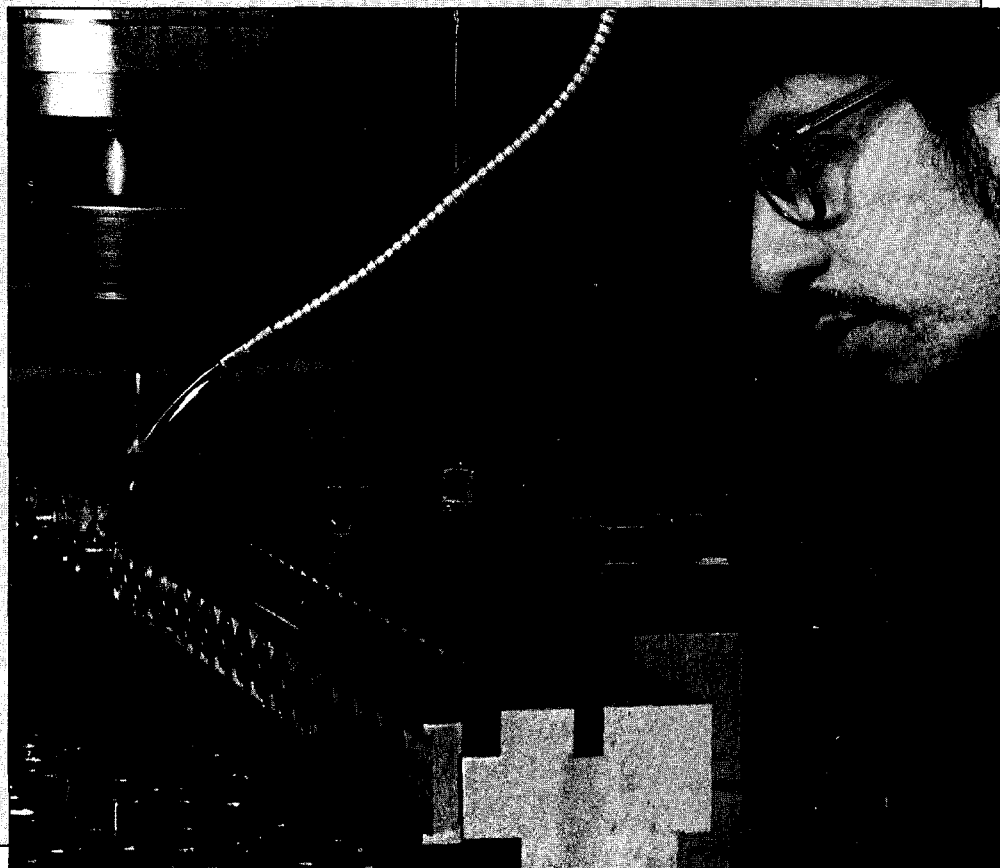
"Quadrupole" in RFQ means that the device has four poles (metal bars) inside a tube and running the length of the tube. The four poles are placed 90 degrees from one another and converge toward

the center of the tube like the spokes of a wheel. The electrical field between the tips of the poles alternates its positive and negative orientation as the particles move down the tube, thus causing a net acceleration and focusing. The tips of the poles, which are nearly smooth on the entry end of the structure, are machined so that they slowly scallop in larger and larger waves toward the exit end. This scalloping is responsible for the inherent bunching and acceleration capability of the structure.

*Alex Lopez of the Shops Department oversees the machining of one of the RFQ vanes.*

*Photo by LeRoy N. Sanchez*

# What's an RFQ?



# Putting the Pieces Together at HEDL

The FMIT facility will produce large quantities of neutrons—uncharged nuclear particles—to test candidate materials for the world's first fusion reactors. This "neutron factory," a joint effort between the Hanford Engineering Development Laboratory (HEDL) and LASL will be located at HEDL in Richland, Washington. LASL, which has an FMIT group (AT-4) under Ed Kernp, will spend \$35 million to \$40 million to design and develop the particle accelerator necessary to drive the neutron-producing facility.

Until now, there has been no appropriate neutron-producing facility where samples of materials for fusion reactor walls could be evaluated. The FMIT will fill this need. It will produce a steady stream of neutrons at the same energy but at even greater intensity than those expected from a fusion reactor. The neutrons will be used to test various materials, such as metal alloys, that will be needed in the reactors. By placing samples in the facility's neutron stream, the effects of fusion neutrons on the candidate materials can be determined and the best materials for the reactor walls can be selected.

Neutrons will be produced in the factory using a form of hydrogen. In nature, about one hydrogen atom in 6,400 has a neutron attached to its single, positively charged proton nucleus. This proton-neutron nucleus is a form of hydrogen called heavy hydrogen, or deuterium. To produce a neutron stream, deuterium is injected into the FMIT and accelerated about 35,000 miles a second, or about one-fifth the speed of light. These high speed deuterium nuclei, called deuterons, pouring out of the accelerator at a rate of a billion-billion a second, each with an energy of 35 million electron volts, are directed onto a target of flowing liquid lithium metal. As they pass through the target, the lithium atoms strip off the deuterons' positively charged protons and let the uncharged neutrons pass through the target toward test samples.

Test samples of candidate materials only a fraction of an inch in size will be placed in the intense neutron stream. Some samples will remain in the stream for only a few minutes, others may be tested for as long as a year. In each case, scientists will look for test samples showing the most resistance to neutron-

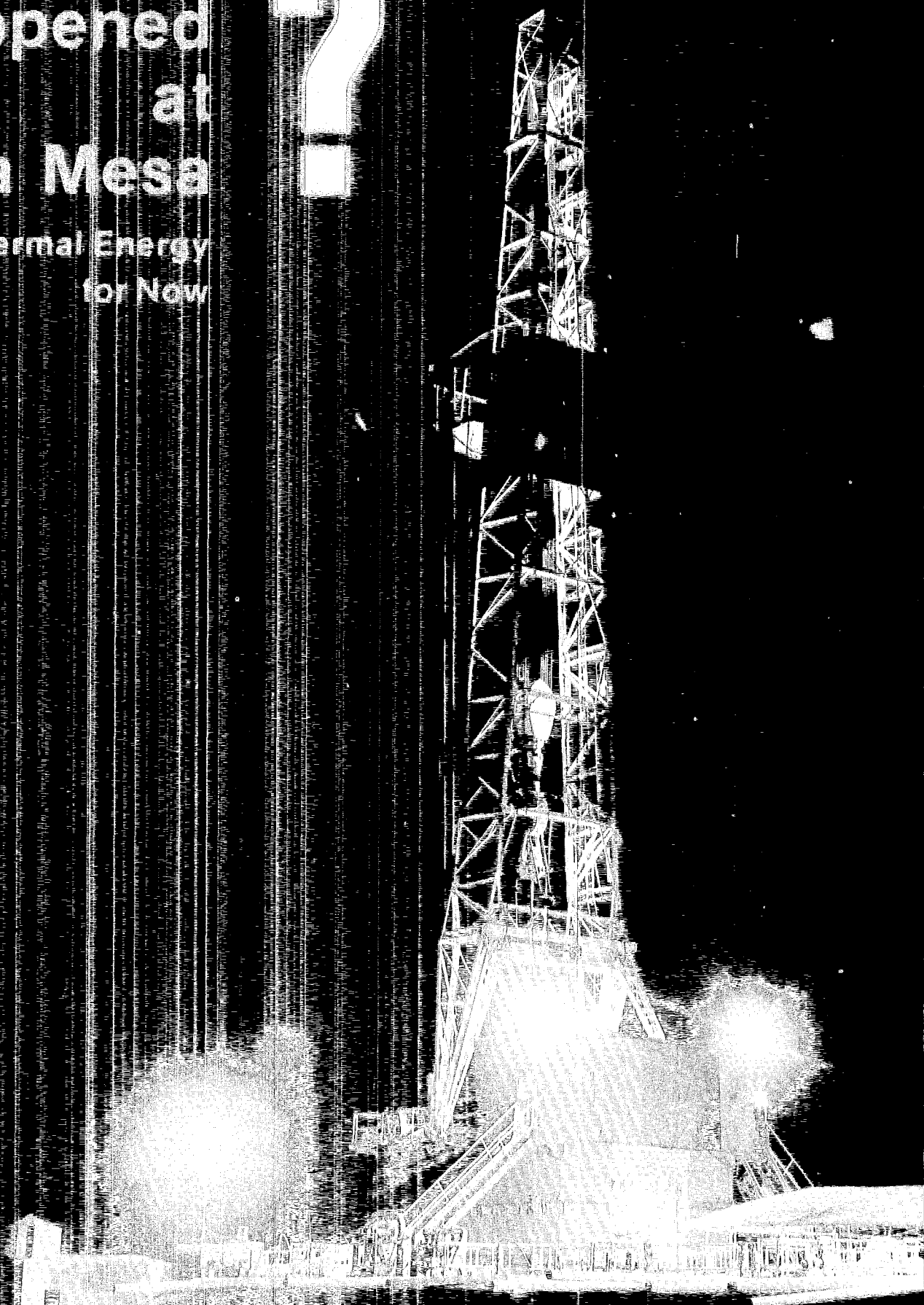
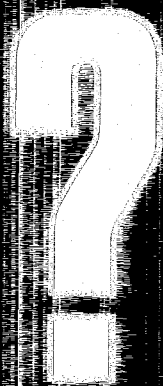
induced damage and thereby will choose the best reactor inner-wall material.

Scientists researching fusion energy believe that it will be the ultimate energy source for our planet. Hydrogen fuel, obtained from water, is abundant, and the amount of radioactivity produced by fusion will be less than the amount produced by fission reactor plants. Scientists continue to work diligently to achieve controlled thermonuclear fusion—which is perhaps the most difficult scientific and engineering problem they have ever faced. Researchers think that they are close to achieving control of fusion; however, beyond this stage much work will be needed to build a power-producing reactor.

The FMIT will make a significant contribution to the first fusion reactor design by providing information for the selection of reactor materials. These contributions will hasten the time when the world will benefit from abundant electrical power produced by fusion.

# What Happened at Sigma Mesa

No Geothermal Energy  
for Now



Last fall, we printed a story about the Laboratory's search for a new energy source on Sigma Mesa. Here is a report on what happened. Funds ran out before a geothermal source was reached, but availability of new funds could renew the project.

By JEANNETTE MORTENSEN

Photos by Bill Jack Rodgers

"Virtually all problems associated with the Sigma Mesa operation can be summed up in two words: lost circulation," said Dick Olwin, LANS manager for the exploratory drilling project.

Lost circulation is a drilling term used to describe the condition when drilling fluid, or mud, leaks into the surrounding formation as a hole is being drilled. Fluids cool and lubricate drill bits, save on their wear and tear, and seal the wall of a borehole in porous formations. Most importantly, fluids clean cuttings from the hole during drilling. When fluid is lost, cuttings may fall onto the drill string and cause downhole tools to jam.

Geoscientists had expected circulation to be a problem to a depth of 600 feet, according to a draft report by Olwin ("Exploratory Geothermal Hole Interim Report"). The ultimate goal at Sigma Mesa was in the neighborhood of 14,000 feet. When circulation was lost at 150 feet, just a few hours after drilling began July 2, 1979, the crew was not surprised. Special additives in the fluid helped for a while, then circulation was again lost at 200 feet.

**Dry drilling attempt**

Crew members decided to try "dry drilling" to 600 feet, where they hoped circulation would no longer pose a problem. Dry drilling is a somewhat misleading term. Drilling mud is still pumped downhole, but it is lost to the surrounding rock rather than returning with the rock cuttings to the surface.

The hole was dry drilled to 600 feet; cement trucks were called in to seal the hole. While awaiting their arrival, the crew continued drilling to 787 feet, where the drill string became stuck.

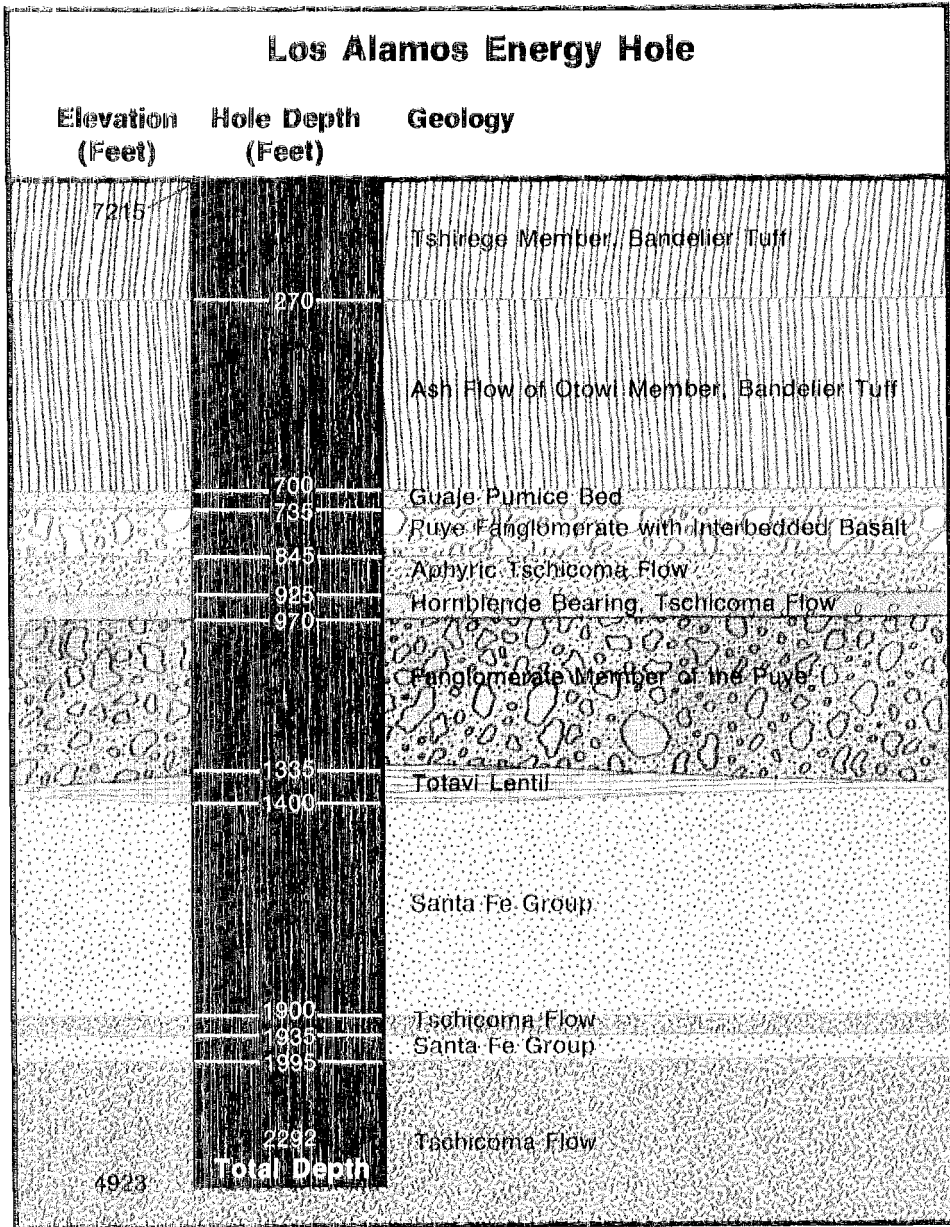
After the drill string was worked free, the hole was completely cemented to the surface. Once again, the rig began to drill— this time in cement. The crew attempted to follow the path of the original hole without wandering into the

porous rock formation, which was softer than the cement and undoubtedly would again cause lost circulation.

Just how difficult is it to redrill a hole with a rotating bit, following a previous path? Draw a wiggly line on a sheet of paper, then try to retrace it with your eyes closed. The task is akin in difficulty to that faced by the drillers.

**2,000 cement sacks**

"Drilling continued in a bootstrapping fashion: drill, lose circulation, cement, drill..." said Olwin. From 700 to 1,400 feet, more than 2,000 sacks of cement were used to plug areas of the borehole where drilling fluid was escaping. Then the cement, too, began disappearing into the formation. In all, thousands of barrels



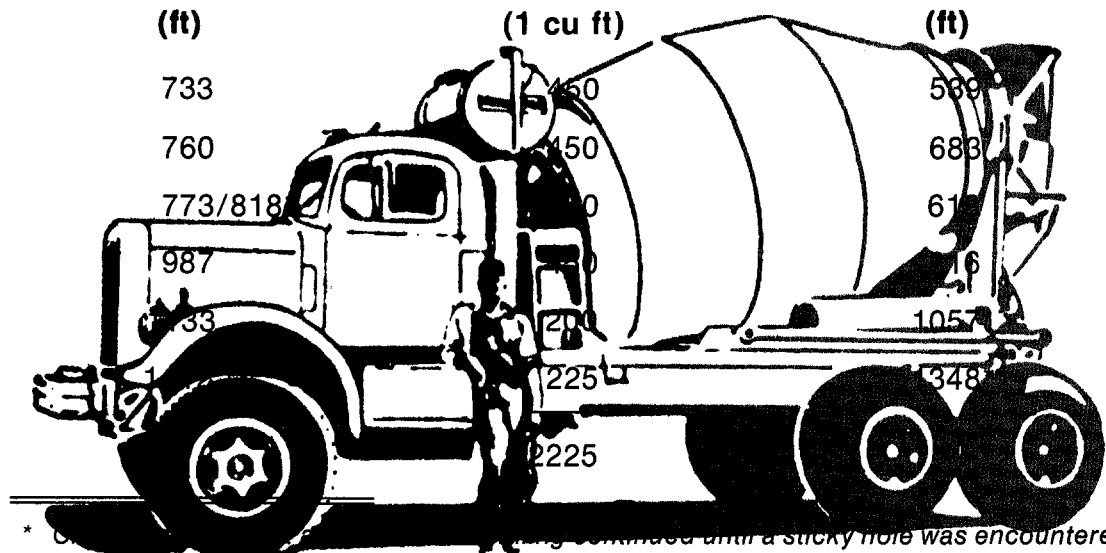
*Last summer the rig worked 'round the clock drilling the rock beneath Sigma Mesa.*

## Lost Circulation Depth      Sacks of Cement Used      Cement Tag Depth

(ft)

(1 cu ft)

(ft)



\* Drilling continued until a sticky hole was encountered at 818 feet.

\*\* First plug set at 1,412 feet.

## The sponge-like rock absorbed thousands of barrels of mud and cement.

of drilling mud and cement were absorbed by the sponge-like rock under Sigma Mesa.

At this point the crew had two choices: to case the hole and reduce its diameter, or to continue dry drilling. The consensus was to continue dry drilling and not case the hole until reaching the bottom of the water table. There, the hole would have to be cased to protect the aquifer.

"Drilling proceeded normally to a depth of 2,292 feet," said Olwin. Then the crew began pulling up the drill string to log the borehole and reconsider casing it. "About 70 feet off the bottom the drill string stopped and could not be pulled up," Olwin recounted. The drill string parted, and consequently about 200 feet of drilling assembly fell to the bottom of the hole.

A "fishing operation" (an attempt to recover the lost tools) continued unsuccessfully for nearly two weeks before the crew decided to drill directionally around the abandoned assembly. The drilling successfully detoured the obstacles, but the borehole walls began caving in on the drill string once the water table was reached.

### Last hope: dual-string

The last hope to save the hole, Olwin felt, rested with a dual-string, reverse-circulation scheme of drilling. This technique has been successful in drilling holes in areas of lost circulation, when standard practices have failed. The scheme differs from conventional drilling in that two concentric drill pipes are used.

In standard drilling, fluid pumped down the center of the drill pipe returns to the surface between the drill pipe and the borehole wall. With the dual-string arrangement, fluid travels down the region between two drill pipes and returns up the center. This method requires less drilling fluid which, contained within the pipe, does not erode the borehole wall.

LASL borrowed the necessary equipment from the Nevada Test Site, where the dual-string technique has proven highly successful. But the project ran into another snag. Only one reverse-circulation drill bit, 17.5 inches in diameter, was available. It was used to drill to 1,993 feet, where it wore out. Larger bits, 26 inches in diameter, were needed to enlarge the hole but would not have been available for two to three months. Other bits on hand were modified, but circulation was never regained using them.

The final operation at Sigma Mesa was casing the hole. The crew had reached 1,993 feet in the "sidetracked" portion, but set casing only to 1,627 feet because of problems in the aquifer zone. The final depth was a far cry short of the planned depth of 10,000 to 14,000 feet. On September 26, 1979, activity at Sigma Mesa ended because all funds had been expended, and none for fiscal year 1980 were available.

### What now?

What happens now? "We still think there's a good opportunity there (Sigma Mesa)," said Ed Sitzberger. "We're trying

## On September 26, 1979, activity at Sigma Mesa ended because all funds had been expended.

to find funds. There are some possibilities that we may try to tap." Sitzberger headed the now-disbanded task group that studied alternative energy sources for the Laboratory.

According to him, LASL is no longer held to the time constraints of a Department of Energy directive requiring national laboratories to reduce natural

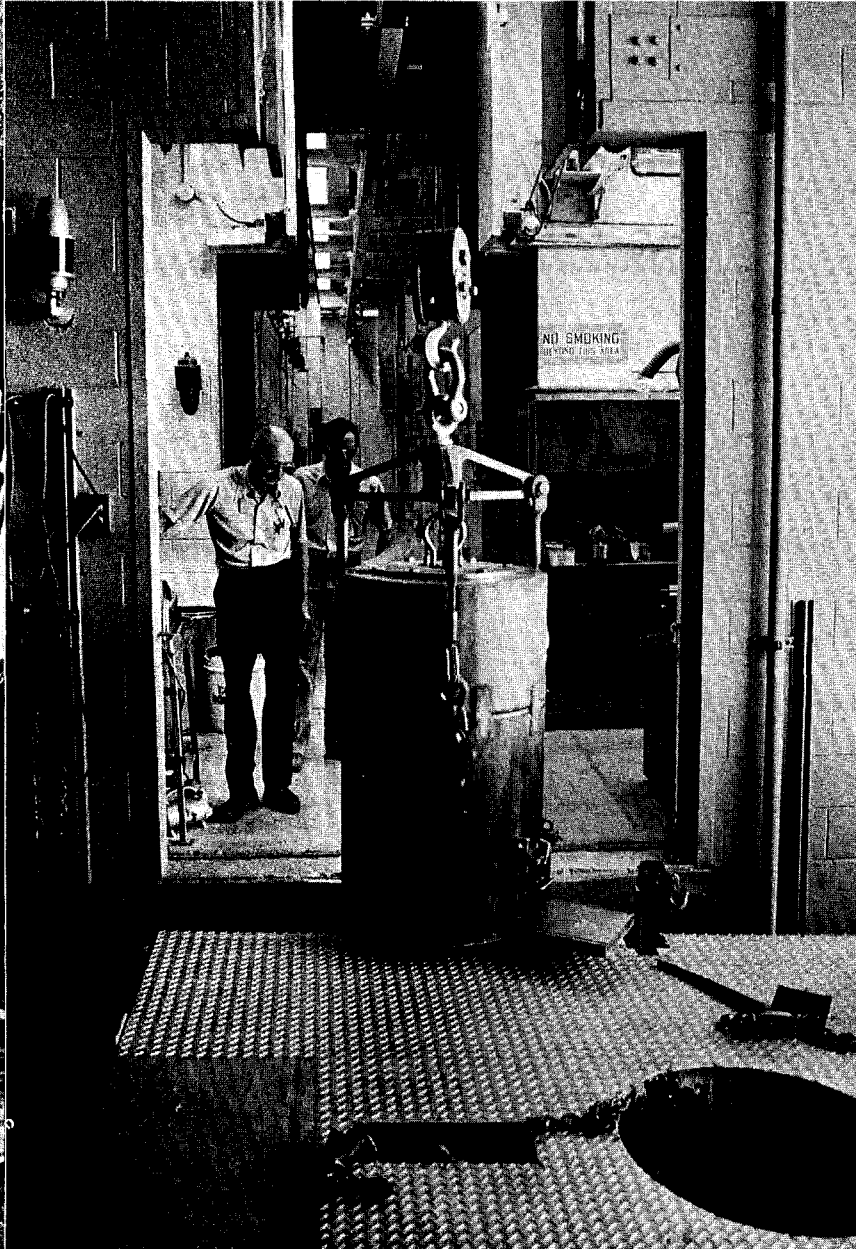
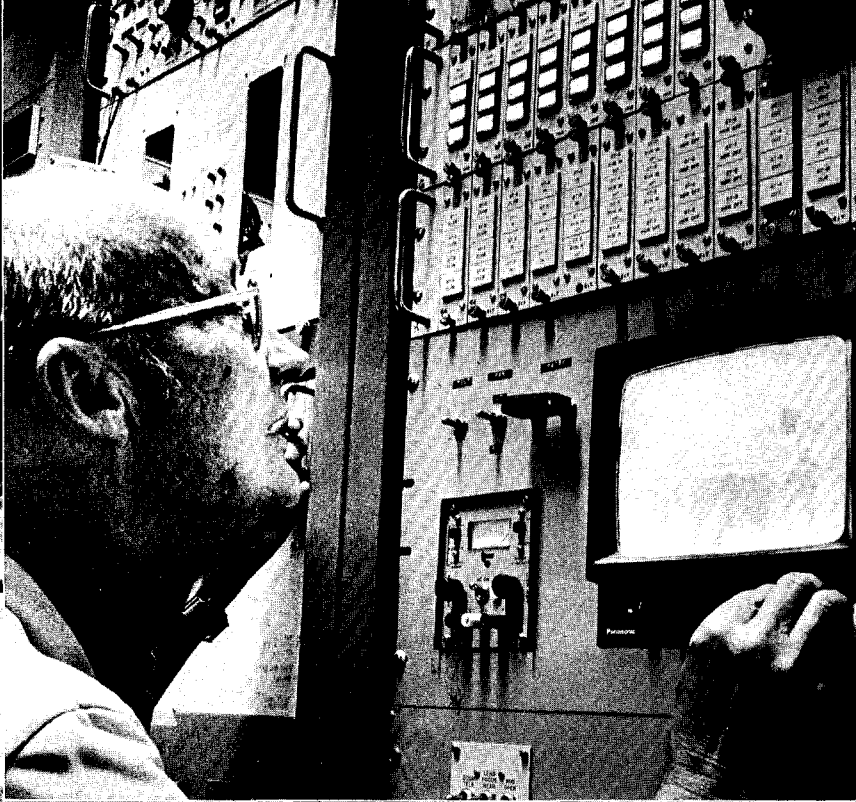
gas consumption by 50 percent by 1985, and to eliminate use of that fuel by 2000. The new policy, said Sitzberger, is to eliminate natural gas usage as soon as is reasonable.

With the experience and hindsight from last year's drilling operation, some funding, and a little luck, LASL may yet tap geothermal energy under Sigma Mesa.

"The assessment of a geothermal resource hasn't changed. We just ran into problems that consumed the dollars," summed up Sitzberger.

*Today the wellhead is covered and the barren site is fenced off. If funds are appropriated, the concrete pad may someday support another drill rig.*





*"... In this country, the responsibility for developing the medical applications of nuclear technology now rests with the recently established Department of Energy. ... We shall ... seek to identify beneficial medical applications of new research findings and ... work to extend these advances into clinical practice."*

*—President Carter, in a message to the Second International Congress of the World Federation of Nuclear Medicine and Biology, September 17-21, 1978.*

# The View from Within

By JEFF PEDERSON and JEANNETTE MORTENSEN

In the nuclear medicine department of a U.S. hospital, Dr. Jordan examines special "photographs" of patients to help him diagnose their conditions and prescribe treatments. Some of the images that he holds against the fluorescent lighting board are standard x-rays, others were unknown a generation ago. They are images of bone structure, internal organs and the whole body produced with a special camera and radiopharmaceuticals.

After studying the static x-ray-like images, Dr. Jordan walks down the corridor and into a room where a patient is lying on a hospital bed. A drum-like device hangs over the patient's chest. Dr. Jordan injects a solution into the patient's vein with a leaded glass syringe and chats briefly with the patient explaining the procedure, then pushes a few buttons and adjusts some dials on an instrument panel hooked up to the drum-like device. A video screen above the panel lights up, displaying a pseudo-color film. The fist-sized organ on the screen

pulsates. An image of the patient's heart is beating before our eyes.

This isn't some vision from a physician's dream or a scene from a science fiction movie. It's reality. Today.

The field of nuclear medicine has come of age. In the 3,000-plus nuclear medicine departments in hospitals across the country, physicians are performing radioisotope "scans" every day. The imaging energy for these scans are not x-rays beamed from a machine. These images are being formed from gamma rays emitted from a radioisotope which concentrates in specific organs or structures of the patient's body.

## Hundreds of isotopes

Atoms with the same number of protons and electrons but differing numbers of neutrons are called isotopes. All the 106 elements have isotopes. Stable isotopes of the same element behave chemically alike, but differ in mass. Radioactive isotopes (radioisotopes) are characterized by unstable nuclei that "decay" by emitting radiation.

The earliest biochemical studies with radioisotopes were conducted in 1924 by George Hevesy who used natural radioactive lead to investigate a biological process. The use of isotopic tracers became popular, however, only after World War II, when artificially produced isotopes were readily available. Today, isotopes for a variety of nuclear

medicine applications are routinely produced in reactors and accelerators and are available through regular medical supply channels.

## The LASL connection

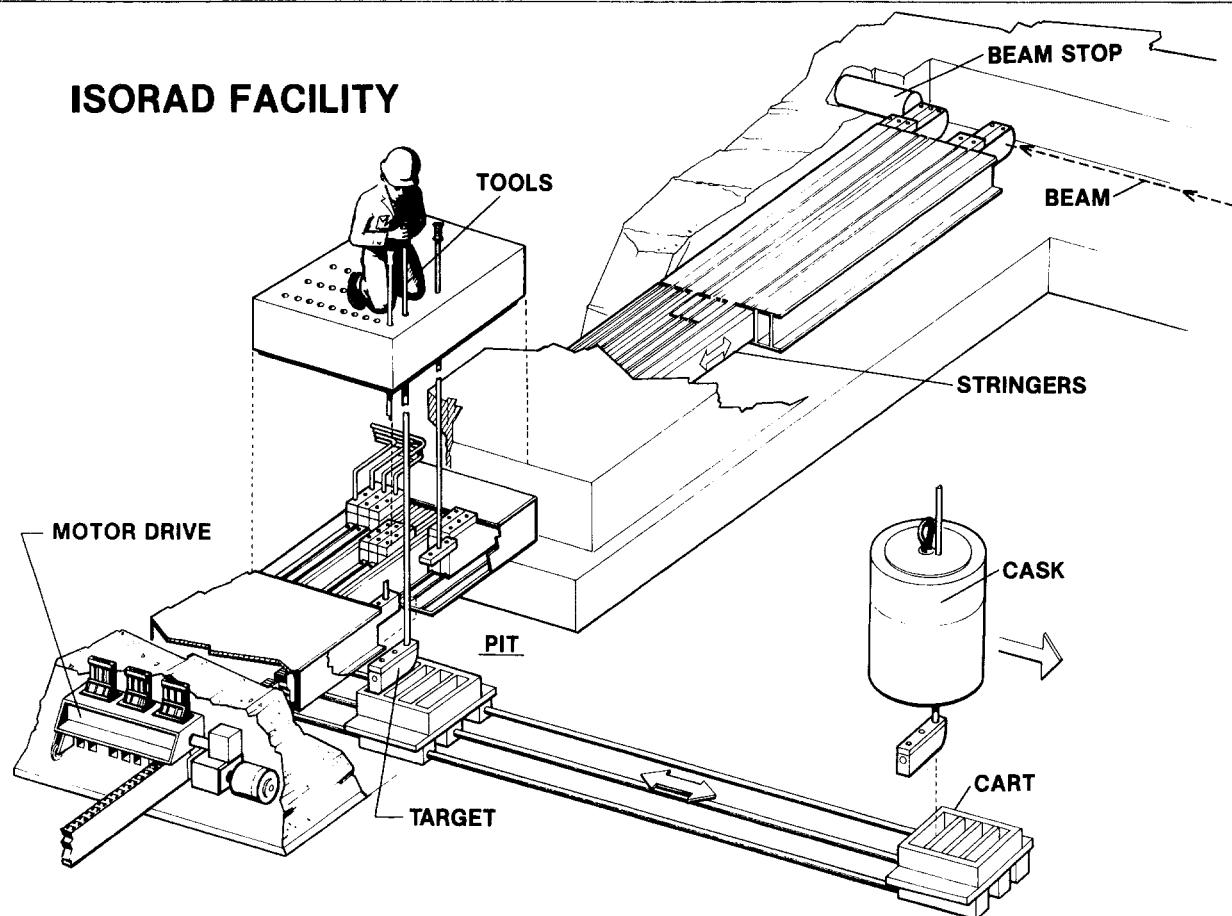
Unique resources of LASL's Nuclear Chemistry Group (CNC-11) and the Clinton P. Anderson Los Alamos Meson Physics Facility (LAMPF) together can produce isotopes that may create a major impact on the nuclear medicine field. LAMPF's intense beam of medium-energy protons can be used to bombard massive targets of pure metals or metal compounds to produce radioisotopes. CNC-11's researchers can chemically separate the medically useful isotopes from the target materials using remote mechanical arms in the group's hot cell facility. Together, LAMPF and CNC-11 can produce unique isotopes that may be used to diagnose and treat patients with a variety of ailments.

Who gets these unique and valuable isotopes? A protocol review committee comprised of nuclear physicians and scientists from across the U.S. meets twice a year to review proposals for LASL-produced isotopes. When a proposal is accepted, the requested isotopes are supplied at no cost to the research group.

The LASL Medical Radioisotopes Research Program concentrates on producing, purifying, and distributing isotopes to collaborating research groups.

*FAR LEFT: Marty Ott inserts the target at the isotope production facility at LAMPF. TOP: Jack Barnes watches the insertion on a remote viewing screen. BOTTOM: Jack Barnes and Ken Thomas oversee delivery of the irradiated target at CNC-11's hot cell facility. The cask, which weighs nearly 6 tons, has just been lifted from the well of the specially designed truck bed. The bottom half of the massive cask is made of depleted uranium encased in steel; the top half is lead.*

## ISORAD FACILITY



*"[Nuclear medicine is] a unique specialty which combines the resources and expertise of chemistry, physics, engineering, and pharmacy with the ultimate aim of medical practice: the diagnosis and treatment of human disease."*

—Senator Hayakawa, *Congressional Record*, Vol. 124, No. 96, June 22, 1978.

"We concentrate on isotopes that we believe can best be made with the LAMPF accelerator," said Hal O'Brien, associate CNC-11 group leader.

### Isotopes in the body

Biological isotopes are administered to patients in low doses, but sensitive equipment can detect and measure the concentration of radioactivity in the body. A variety of instruments can be used: relatively simple detection devices like Geiger counters can measure the radioactivity; sophisticated electronic equipment can produce images of certain organs or the entire body.

Different isotopes are suitable for different needs. Iodine is taken up by the thyroid gland, for instance, and thallium and rubidium concentrate in heart tissue. An isotope may also be incorporated in a chemical compound ("tagged" or "labeled") to control the absorption site of the isotope. For example, technetium-99m can be tagged to a wealth of pharmaceuticals to modify the distribution of the isotope in the body.

Technetium, a reactor-produced element, has no natural biochemistry. It and its derivatives have been used in imaging the whole skeleton, liver, kidney and brain. Its versatility stems from the ease with which it may be reacted with a

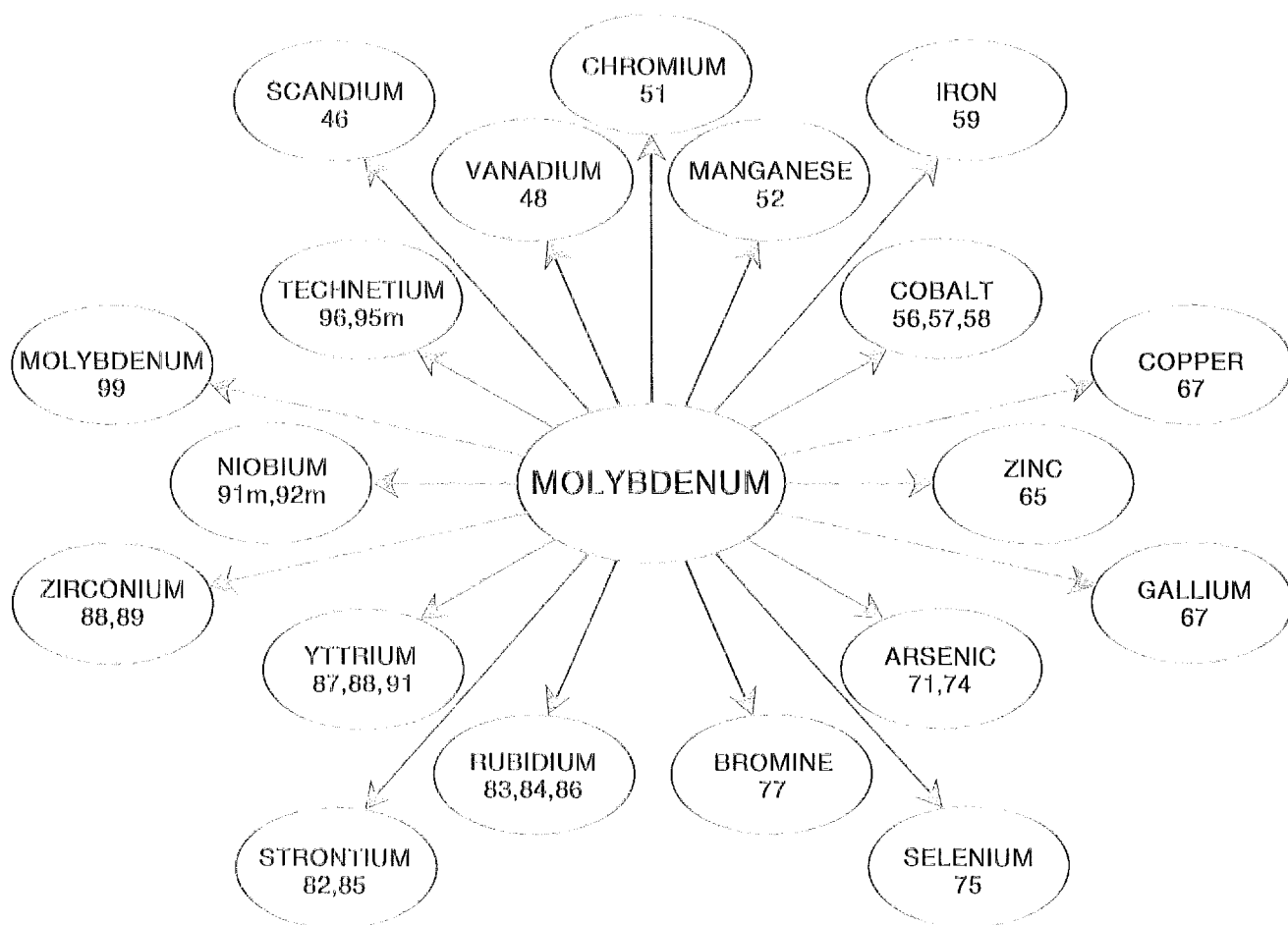
host of biochemicals to control where the isotope concentrates.

In addition to technetium-99m, other "workhorse" isotopes—those used extensively for routine medical diagnoses—include iodine-131 and xenon-133 (reactor-produced) along with gallium-67, iodine-123 and thallium-201 (produced in low-energy accelerators). Many commercial firms supply the nation's "nuclear medicine chest" with these isotopes.

### Positron emitters

Many radioisotopes produced by proton accelerators decay by emitting a positron—a particle similar to an electron, but with a positive charge. When positrons and electrons react, they are converted into energy in the form of gamma rays. The production of positron-emitting isotopes has led to the development of positron imaging devices with applications that far surpass conventional techniques such as x-rays. "The emergence of positron scanning has opened a broad spectrum of radioisotopes that are potentially useful in medicine," said O'Brien.

Early research into positron imaging used carbon-11, nitrogen-13 and oxygen-15 because these elements are the building blocks of biochemicals.



*When a molybdenum target is irradiated with protons, the above radioisotopes are produced.*

These isotopes, however, have not found widespread applications because their short half-lives (20, 10 and 2 minutes, respectively) require a researcher to have access to a low-energy accelerator near the clinical lab. At LASL, the radioisotopes team has been studying ways to make longer-lived positron-emitting isotopes for medicine.

#### **"Milking the cow"**

One way to provide short-lived radioisotopes to users in all parts of the country is to make a long-lived "parent" that decays to a useful, short-lived "daughter" which is easy to separate. Using such a system to generate one isotope from another is called "milking the cow." Pat Grant and Richard Whipple at CNC-11 have been leading the LASL effort in this direction.

The parent and daughter may be efficiently separated by exploiting the chemical differences between the two, yielding what's called a radionuclide generator. If a generator is to be used for biomedical purposes, it must meet three

important requirements: (1) the daughter must be able to be completely separated from the parent; (2) the separation must be simple and reliable; and (3) the daughter must be able to be rapidly administered to a patient in a biologically compatible form.

Ion exchange is one common method of separating parent from daughter. Others include distillation and solvent extraction. In ion exchange, the parent is adsorbed on a resin column and "generates" the daughter through radioactive decay. At certain intervals, a dose of the daughter can be removed while leaving the parent activity on the column to produce additional daughter doses. The process of ion exchange is similar to what occurs in commercial water softening equipment, where magnesium and calcium ions are removed from hard water and are replaced with sodium ions to make soft water.

Strontium-82 was the first isotope produced at LAMPF and shipped to an outside group (in 1974). Coupled with its daughter, rubidium-82, it was the first biomedical generator system developed by CNC-11. The generator's half-life is about 2 months, and the daughter can be milked from the parent every 10 minutes during that period.

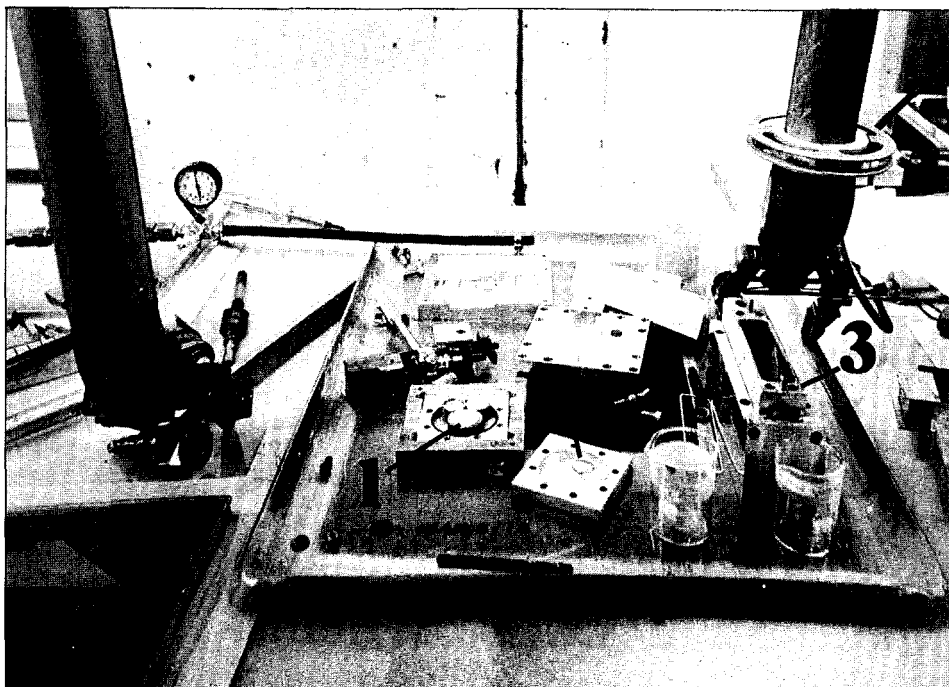
#### **Promising imaging agents**

CNC-11 is the only supplier of rubidium-82, an isotope being evaluated as a heart imaging agent and in kidney and tumor research at the Donner Laboratory of Lawrence Berkeley Laboratory; Massachusetts General Hospital; Franklin McLean Memorial Research Institute at the University of Chicago; the University of California at San Diego; and Hammersmith Hospital in London, England. Other promising generators developed or under study here include hafnium-172/lutetium-172, germanium-68/gallium-68, and cadmium-109/silver-109m.

Allen Ogard of CNC-11 has been studying the cadmium-silver generator system in hope of yielding a tracer that is soluble in blood. Other CNC-11 researchers, in collaboration with Milton Kahn at the University of New Mexico and some of his graduate students, are developing a generator system for germanium-68, which results in gallium-68, a positron emitter. Grant and Whipple are evaluating separation techniques that are quick, efficient, and provide a more versatile product than commercial generators currently available.

*"... Nuclear medicine has the facility to produce studies of the body's actual functioning rather than merely its structure alone. This capacity for physiological investigation, now in the process of being greatly extended by computer technology, offers possibilities for patients with a wide range of illnesses, in particular, heart disease and cancer."*

—Senator Hayakawa, Congressional Record, Vol. 124, No. 96, June 22, 1978



## History

The Laboratory's research team has passed several milestones since the early part of the decade, when the isotope program was conceived. "We had a difficult time at first convincing the people at headquarters (then the Atomic Energy Commission) that LASL could make unique contributions to the nuclear medicine program," O'Brien recalled. "If it weren't for the support of people like Louis Rosen (MP-Division leader), George Cowan (now an associate director at LASL), Jim Sattizahn (CNC-11 group leader) and others, I doubt that we would have a viable program today."

The Isotope Production Facility went into operation at LAMPF in October 1976. The program had begun two years earlier, but the first irradiations of targets revealed some problems. Ogard, together with Charles Cummings of WX-4, tackled the problems in a major reworking of the isotope production system. Since then there have been no serious operating difficulties.

The isotope production facility has nine independent target stations located at the end of the accelerator's main beam line. The targets, which are inserted into the beam and retrieved with a rail-like transporter, have only minimal effects on other experiments being simultaneously conducted at LAMPF.

*TOP: Behind the lead glass windows, the targets are removed from the gold-plated copper "screwed can." Two stacks of 0.75-inch-diameter disks and one stack of 1-inch-diameter disks form the cloverleaf shape (1). One disk is stuck to the top of the screwed can (2). The target carrier box (3) is the first all-aluminum one used by CNC-11. BOTTOM: Marty Ott uses mechanical manipulators to chemically process irradiated molybdenum disks and isolate the bromine-77 isotope. He uses a mixture of nitric and phosphoric acids to dissolve the metal.*

*Photos by John Flower*

### Every element

Chemically isolating the desired isotope from the target is one of the most difficult steps in the isotope production process. Complex interactions that yield many isotopes result from irradiating a target with 800-MeV protons. For example, if a nickel target is irradiated, the team may end up with as many as 29 elements being produced—everything from hydrogen to copper.

Isolating the desired isotopes can be a time-consuming task. Once a procedure is established, Jack Barnes and Glenn Bentley of CNC-11 are responsible for making the procedure compatible with remote hot-cell operations. They have developed remote wet chemistry processes for isolating bromine-77, strontium-82, yttrium-88 and zirconium-88 from molybdenum targets. Tantalum targets have yielded hafnium-172 and the rare earth elements. Iron-52 has come from a nickel target. Xenon-127 has been produced from a lanthanum oxide target. A target of rubidium bromide has yielded germanium-68.

The intense radioactivity of the targets creates problems for the chemist. Materials usually considered inert, such as Teflon and other plastics, are made brittle through radiation damage. Ion exchange resins become more susceptible to attack by corrosive chemicals. Vycor (synthetic quartz) glassware becomes so dark that it's impossible to see through.

Another concern is heat deposited in the target and its holder while being irradiated by the 400-kilowatt proton beam. Don Grisham of MP-7 and Bruce Erdal of CNC-11 were instrumental in

*This image of a white laboratory rat was produced with CNC-11's gamma imaging camera. The rat was injected with pyrophosphate labeled with technetium-99m, and the image was made 24 hours later. The radiopharmaceutical primarily concentrated in the bones.*

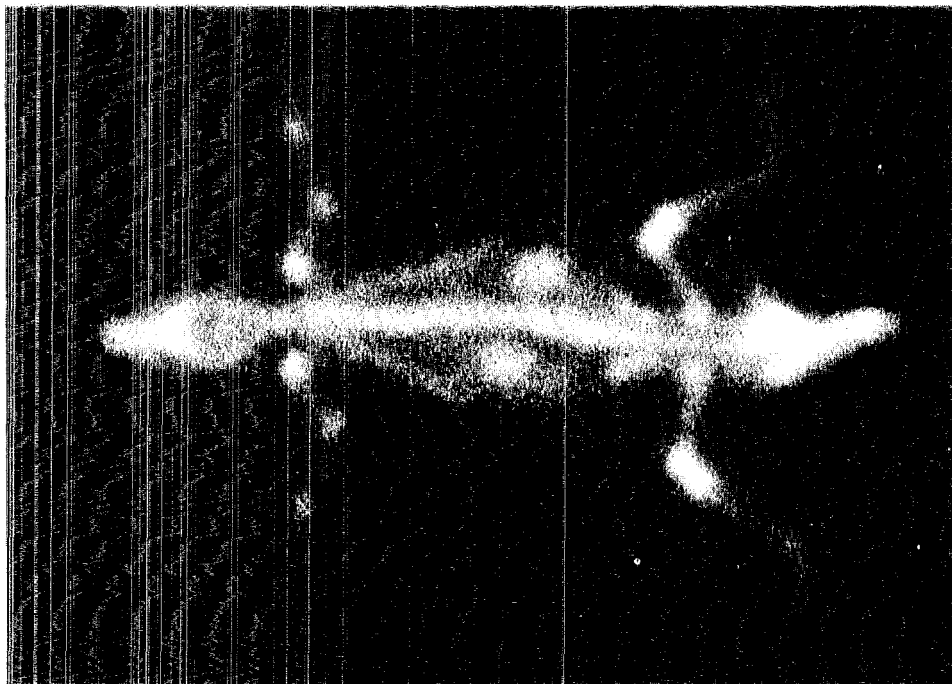
## Inside View

An exciting development in diagnostic imaging is the computerized axial tomographic (CAT) scanner. It produces clear cross-sectional images of parts of the body, a slice at a time.

With the CAT scanner, a narrow beam of x rays is passed through the body, and the photons are detected in patterns on the other side, as different densities of body parts affect the beam. Data from each cross-sectional study are stored in a computer and processed with a three-dimensional program to reconstruct the image.

In a different type of imaging that uses positron emissions (ECAT scanning), radioisotopes that emit positrons as they decay are attached to specific compounds. The compound is injected into a patient, and its movement is followed.

The site of an abnormality can be pinpointed as the annihilation photons are detected in coincidence, in a variation of the triangulation method used by sailors. Studying the times and routes of these agents permits more exact research in complex organs, such as the brain.



modifying a computer code for calculating proton-induced heating in targets. The computer program can draw a complete temperature profile for each target. If the melting point of the metal target is to be approached, CNC-11 first conducts experiments to determine whether heating problems might result during irradiation.

The temperature of the water-cooled target often approaches 300°C. A loss of coolant accident could result in temperatures as high as 3000°C—above the melting point of most metals.

### Where to hang an isotope

A developing segment of the LASL isotope program is the biomedical compound labeling effort. This research, conducted by Phil Wanek and Scott Wilbur of CNC-11, has produced significant results over the past three years. Their work focuses on attempting to understand the chemical mechanisms that can be exploited to tag radioactive isotopes to biochemicals; the synthesis of new labeled biochemicals; and the development of new "cold kits" that can be applied to diagnosing and treating disease.

A cold kit, whether commercial or LASL-made, consists of non-radioactive chemical reagents that will quickly produce a labeled biochemical when properly reacted. Kits are measured, packaged and sterilized in advance. Exact instructions are provided to the user, who follows a sequence of steps so that the isotope can be incorporated into the biochemical agent just before it is needed. Cold kits are efficient packages that allow a user to quickly label and use the radiopharmaceutical before radioactive decay makes the product unusable. The LASL team has developed two kits for radioactive iodine. The first was for rose bengal (tetrachloro-tetraiodofluorescein), a dye used to study diseases of the liver and gall bladder; the second was a method for tagging o-iodohippuric acid, a biochemical useful in kidney studies.

Wilbur is investigating labeled tetracycline for cancer diagnosis,

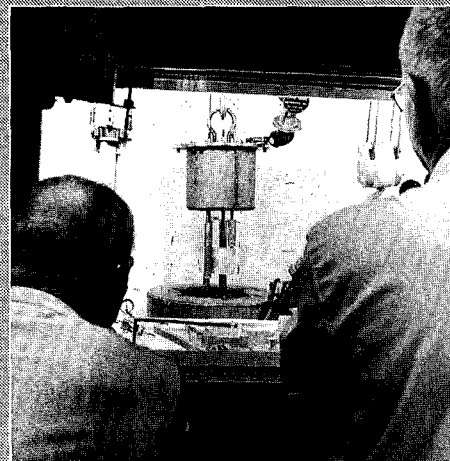
aliphatic fatty acids for heart studies, and specific steroids for early detection of breast and prostate cancer.

### Imaging camera

The group recently acquired a gamma imaging camera that allows CNC-11 researchers to study the movements of radioactive biochemicals in animals. The camera contains photomultiplier tubes and a specially grown crystal of sodium iodide, about 12 inches in diameter. Impurities of thallium in the crystal cause gamma rays, given off by radioisotopes, to be converted to a pulse of visible light through the process of scintillation. These light pulses, amplified and analyzed, result in x-ray-like images. The advantages that the imaging camera/radioisotope combination has over x-rays are: (1) organs and structures that are difficult, if not impossible, to x-ray can be imaged, (2) series of dynamic, rather than static, images can be produced with a low-dose radioisotope, whereas a series of x-rays would result in the patient receiving higher radiation doses and (3) sites of abnormal functioning, which could not be seen on x-rays, can be detected early. Another advantage of radioisotope imaging is that it is a non-invasive technique. For a patient who has suffered a severe heart attack, a heart scan with thallium-201 is considered safer than alternative invasive procedures, such as angiograms.

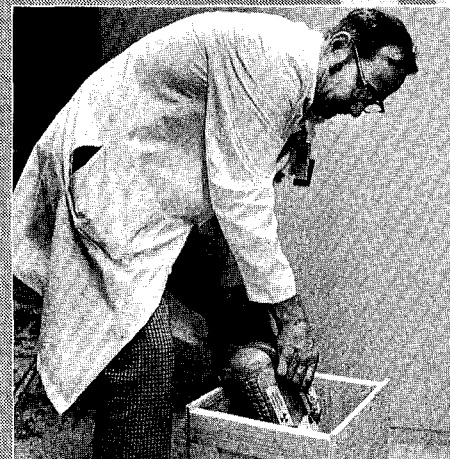
These results in nuclear medicine have required the cooperation of many specialists in different fields. The combination of unique facilities at LASL, the varied expertise and dedication of CNC-11 employees, and their interactions with outside researchers have resulted in a research program with the potential of further advancing the growing field of nuclear medicine.

"That we have been able to accomplish certain goals is a tribute to the enthusiasm of all those associated with the program," said O'Brien. "We feel this is a frontier."



Jack Barnes (left) and Tom DeBusk remove the irradiated target from the cask inside the hot cell. The target material (in this case stacks of molybdenum disks) is inside the rectangular box, which is attached to the short cylinder hanging from the top of the cask. DeBusk redesigned the holder to carry as many as three target containers simultaneously.

Photo by John Flower



Marty Ott places a 50-pound "pig," which shields the radioisotope, in a crate for shipment. (The "B-57 pigs" are surplus items from the days when particulate samples from atmospheric tests were collected.) The bromine-77 will be sent to several users across the country who label various pharmaceuticals with the isotope and study their properties.

Photo by John Flower

# BEAT THE CLOCK

Although Los Alamos is considered isolated from major transportation centers, the medical isotope group has worked with Carl Buckland of H-1 and John Ramsey and others of Supply

and Property (SP) so that CNC-11 can ship short-lived isotopes to users with a minimum of delay. A sample timetable follows.

Thursday, 8 a.m.

Molybdenum metal target is inserted in LAMPF's beam line.

Monday, 8 a.m.

Target is withdrawn from the beam line.

Monday, 8:30 a.m.

Target is trucked in a protective cask from LAMPF to the CNC-11 hot cell facility at TA-48. Cask is remotely opened in hot cell and irradiated target removed. The target sits in the hot cell to allow the krypton-77 (1.2-hour half-life) to decay to less radioactive products.

Tuesday, 8 a.m.

Material is shuttled by mini-train to nearby wet chemistry hot cell where the target material is processed to isolate the isotope bromine-77.

Tuesday, 1 p.m.

Chemical processing finished. The isotope is assayed to determine the amount recovered. The sample is split into portions to meet users' requirements.

Tuesday, 2 p.m.

CNC employees package the vials, which contain several hundred millicuries\* of bromine-77 (less than  $10^{-12}$  grams). The vials are packaged in leak-proof, shielded canisters, which are packed in wooden boxes.

Tuesday, 3 p.m.

The boxes are delivered to Supply and Property.

Tuesday, 5 p.m.

SP delivers shipments to Ross Airlines at Los Alamos airport.

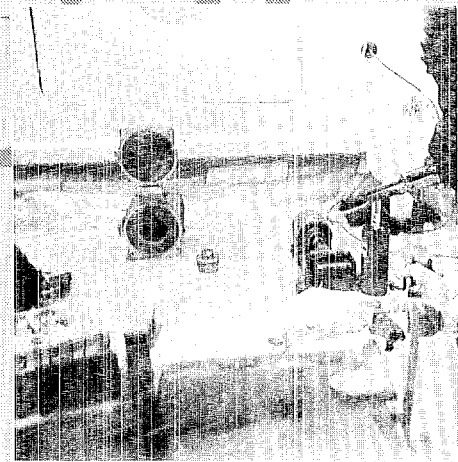
Tuesday, 6 p.m.

Shipments arrive in Albuquerque and are flown to their destinations by Federal Express.

Wednesday morning

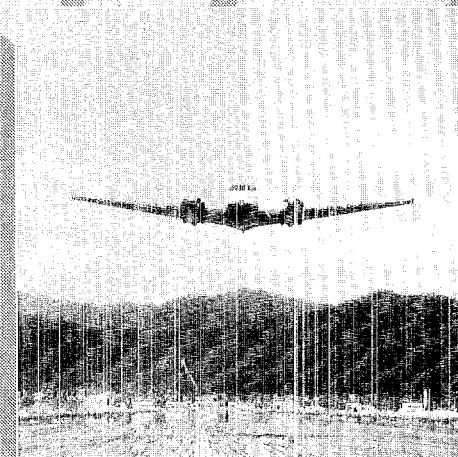
Shipments arrive in Kansas City, St. Louis, and Washington, D.C. About 1 half-life of the 56-hour bromine-77 has elapsed.

\*A curie is a unit of radioactivity equivalent to the amount of any radioactive nuclide that decays at the rate of 37 billion disintegrations per second.



Inside cell #11, a mechanical arm inserts a glass vial with the bromine-77 solution into a leak-proof, shielded inner liner. The liner fits in the lead "pig" on the left in preparation for shipment.

Photo by John Flower



# The Patient's Viewpoint

The Society of Nuclear Medicine estimates that on the average a nuclear medicine procedure is performed on one out of two patients admitted to U.S. hospitals. Last year, more than 37 million people were admitted to hospitals in this country. Perhaps you're one of the millions of Americans who have had a tracer or scan. If not, and if you're curious about it, read the following recollections of two Laboratory employees.

Neither of these patients took a radioisotope produced by CNC-11, but perhaps some day you, or someone you know, will.

## Doris Wilhelm

One morning in 1971, Doris Wilhelm found a lump on her neck. Her doctor told her to postpone her impending trip to Hawaii until the results of laboratory tests were in. One of the tests involved taking radioactive iodine, I-131.

"We had been up here for 24 years," recalled Wilhelm, now a

clerk/receptionist in ISD-7. "My husband was a chemist with the Lab at the time, working with radiation. I wasn't afraid about taking it.

"It wasn't hard to swallow. The pill was just a little larger than a vitamin capsule. I had to go back to the hospital, I think, 24 hours after taking it," she said.

Wilhelm recalled sitting in a chair in the basement of the Los Alamos Medical Center while a technician, using a hand-held instrument, traced the radioactivity. The results turned out negative, which meant the thyroid itself wasn't affected.

"I had no ill effects from taking the capsule," Wilhelm said. "I think in 48 or 72 hours, I was told, all traces of it were gone."

Two weeks later Wilhelm was operated on to have the lump removed. "It turned out it was neither a thyroid problem nor a malignancy, just a benign lump," she explained.

"I was in Hawaii two weeks to the day after they operated," Wilhelm said. "I was determined I was going to get there. We stayed three weeks. I probably got more radiation from the sun in Hawaii than I did from the iodine capsule."

"I had no qualms about taking the capsule. Who had any alternatives," she asked rhetorically. "Radiation doesn't frighten me. If more people would become aware of how much it takes to hurt you, they wouldn't be so afraid of it."



Photo by LeRoy N. Sanchez

### Silvio Balestrini

About 20 months ago, after suffering two heart attacks, Silvio Balestrini was preparing to have bypass surgery. At Presbyterian Hospital in Albuquerque, he had an angiogram, but because the catheter didn't reach Balestrini's aorta, his physician decided to run a heart scan to ascertain if the aorta was partially blocked.

Balestrini is a member of CNC-11 but does not work on the radioisotope program.

"They put me on a treadmill, and when I thought I could go only about 30 seconds longer, I was to tell them," Balestrini recalled. "They already had the needle in my arm. All they had to do was push the plunger."

When the heart is beating rapidly, thallium, like its chemical cousin potassium, tends to concentrate in the heart.

"They injected thallium chloride." Balestrini continued with a scientist's precision, "I calculated that I got about  $10^{12}$  atoms of the radioisotope. The isotope I had was thallium-201—about a milli-microgram ( $3 \times 10^{-10}$  grams). It has a half-life of 73 hours," Balestrini explained.

"About 20 minutes later they placed me under a sensitive gamma detector," Balestrini said. When he saw the image of his heart appear on the screen, he got scared. "There was a dark shadow on one side," he said dramatically. He paused, then clutched his hand to his breast. "It was from my pen in my pocket," he chuckled.

From the scan Balestrini said his doctors learned that the aorta wasn't blocked, and they got a good idea of what they were going to find when they opened him up. He was scheduled for surgery the following Monday.

The day after the scan, he stopped by his office. "I came in here and set off the alarm (on a radiation detector)," Balestrini recalled with a grin. "I knew I would because it was only 24 hours later and I still had..." he punched out the figures on his pocket calculator, "... about 80 percent of the activity."

The health monitors, who knew of Balestrini's radioisotope scan, went along with the gag. They ran their detectors over him from head to toe as though he were a contaminated piece of equipment. "They even filled out a tag with the proper signatures and pinned it on me," he said, "so I could legally get out of the lab."



Photo by John Flower



*Posterization by Chris J. Lindberg*

# **CAVE KIVA**

## **Gallery of an Ancient Artist**

**Photos by Dave Moore**

**“... one of the great art treasures  
of the Southwest.”**



*FAR LEFT: A long line of hopefuls waits for the opportunity to get inside the cave. LEFT: Kokopelli captures the hearts of visitors.*

It was a great day for a hike. Not too windy, not too hot. A warm spring sun illuminated the tan Bandelier tuff cliffs enclosing Mortandad canyon. It was a perfect day to accept the Laboratory's invitation to explore Cave Kiva.

Visitors came by the hundreds. (The turnout was estimated at about 1500.) They left their cars by the roadside and hiked three quarters of a mile to the cave. During the brief, 20-minute hike, they left today behind and stepped back into a world 500 years old. They followed a natural path etched into the mesa by early Pueblo Indians. Along the way, they had the opportunity to view a game pit, a plaza site with the remains of a subterranean kiva, and at least 50 small caves carved into the north side of the canyon's face. But they came to see only one.

Two H-8 employees, Brent Bowen and Donald Van Etten, pointed hikers in the right direction and helped get them in and out of the cave. Charlie Steen, consulting archaeologist for the Lab, was on hand to tell the story of Cave Kiva and answer questions.

The long line of those hoping to get into the cave represented a wait of one to two hours. For those patient and fortunate 439 who got in, it was worth the wait. Inside, Steen explained the significance of the cave and its rock art.

Referring to the art, Steen remarked, "As far as I know, it doesn't tell a story." But Steen, as always, had a fascinating story to tell.

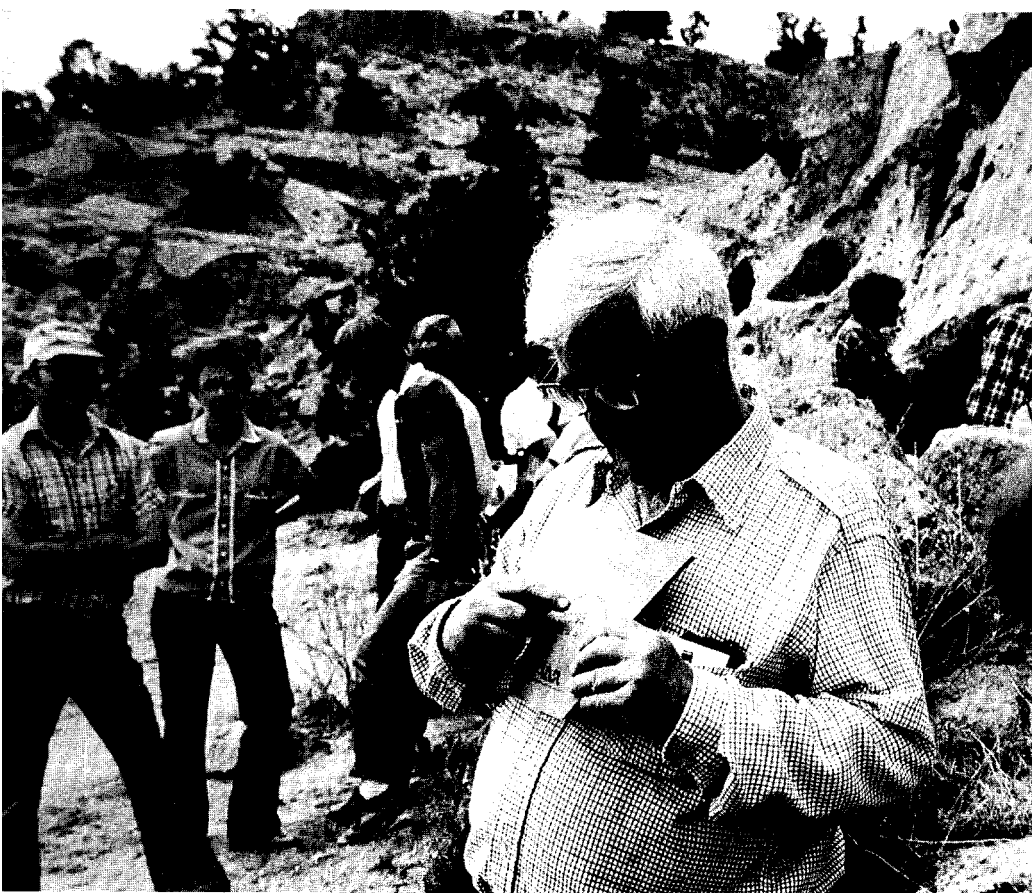
The figures carved in the wall are "truly unique," he told his willingly captive audience. "There's no other rock art like it in the Southwest." And fortunately for us it's some of the best preserved. "It's almost in the same condition as when the Indians left it," he added.

The reason that it's so well preserved is "pure chance," explained Steen. It's just luck that the surface of the cave's walls never sloughed off like those of so many other caves in the area.

This type of rock art is not widespread. "It appears in an area about 10 miles in length and less than a mile east to west. And it was

**"The Kokopelli cult was widespread for several hundred years. Some people think he was a real person."**

**“There’s no other rock art like it in the Southwest.”**



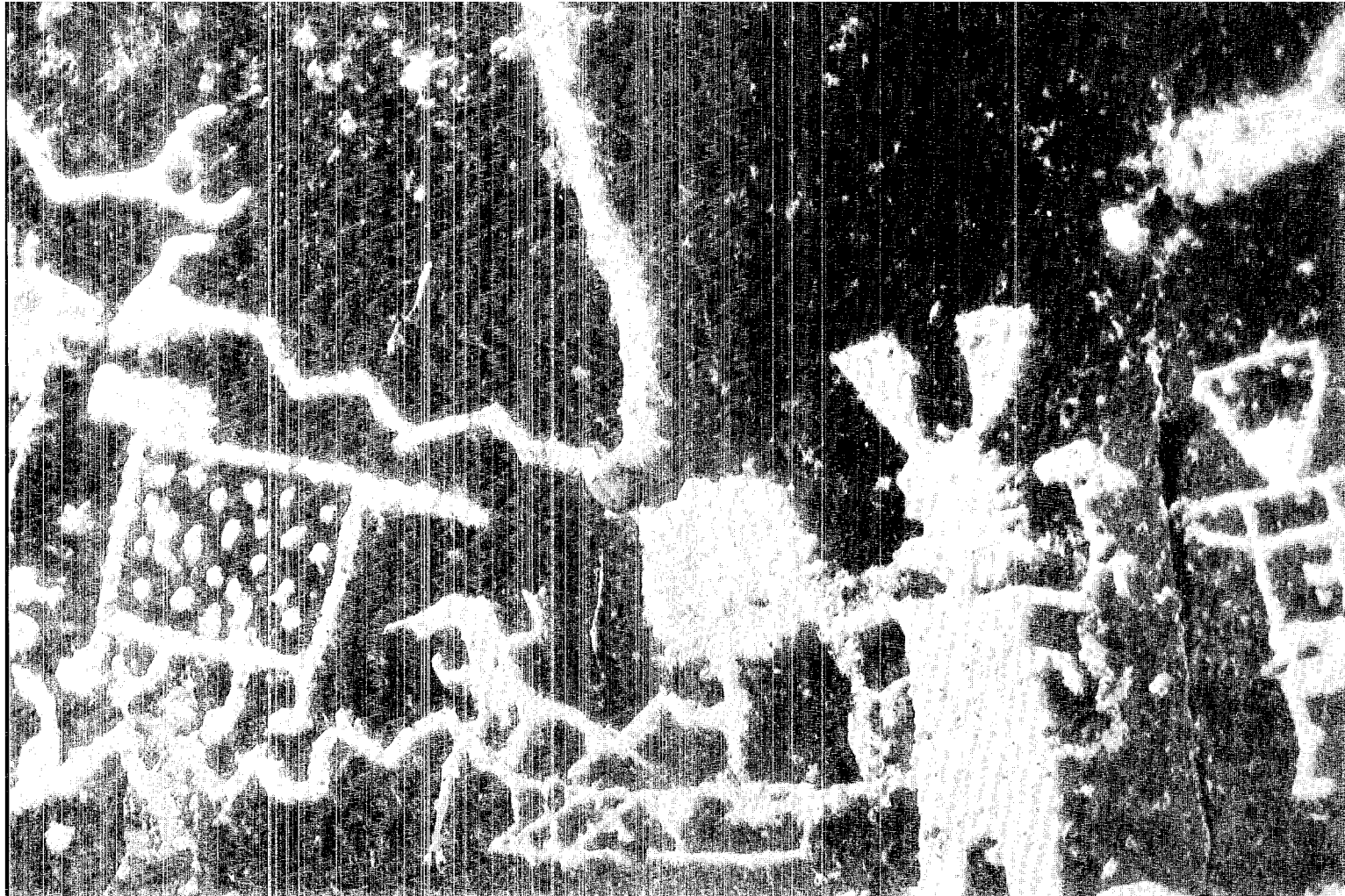
prevalent only from the late 14th to early 15th century,” said Steen. Archaeologists have been able to pinpoint those dates from pottery sherds found in the caves.

The art in each kiva was done by a different artist, said Steen. The artists used sharp, charred wooden stakes—and undoubtedly a lot of “elbow grease”—to carve their work into the smoked walls.

Cave Kiva became part of the Laboratory’s domain around 1960, when the nearby truck route was constructed. About five years ago, after vandals hit, the Laboratory installed a grate to seal off the entrance to the cave and protect its contents for posterity. The inconvenience of the grate and small “doorway” restricted the flow of visitors. And once inside the 10 by 12 foot room, visitors had to crowd together while listening to Steen’s story.

They learned that the spotted animals drawn on the walls probably

*Charlie Steen, LASL’s consultant archaeologist, tells visitors the story of the cave.*



represent jaguars, the figure with the shield body is a Toltec sun god, and the horned serpent is closely related to the plumed serpent that often appears in Mexican art.

According to Steen, there was much interaction between the Indians in the Southwest and those in Mexico. As further proof of their interactions, he explained, turquoise and lead proved to be from mineral workings around Santa Fe have been found in pre-Columbian art.

Perhaps the favorite drawing in the cave is that of Kokopelli—a Hopi name. “He apparently was someone who chased the girls,” Steen said with a gleam in his eyes. Always shown sexually aroused, Kokopelli was the “culture hero” or sex symbol of his day. On one wall a club bearer sneaks up behind Kokopelli, ready to strike. Perhaps a jealous husband? “The Kokopelli cult was widespread for several hundred years. Some people think he was a real person,” Steen explained.

“I’ve said it so many times that it’s almost a cliché,” repeated Steen for emphasis. But for those who hadn’t heard his opinion, he continued: “I

consider Cave Kiva one of the great art treasures of the Southwest.”

For those who weren’t fortunate enough to get into the cave to view the treasure, Steen has announced that they’ll have another opportunity. Over a two-year period, tours will be scheduled for the Laboratory’s four most popular archaeological sites—Tsirege, Nakimuu (at S-Site), the ruins at PHERMEX, and then again Cave Kiva.

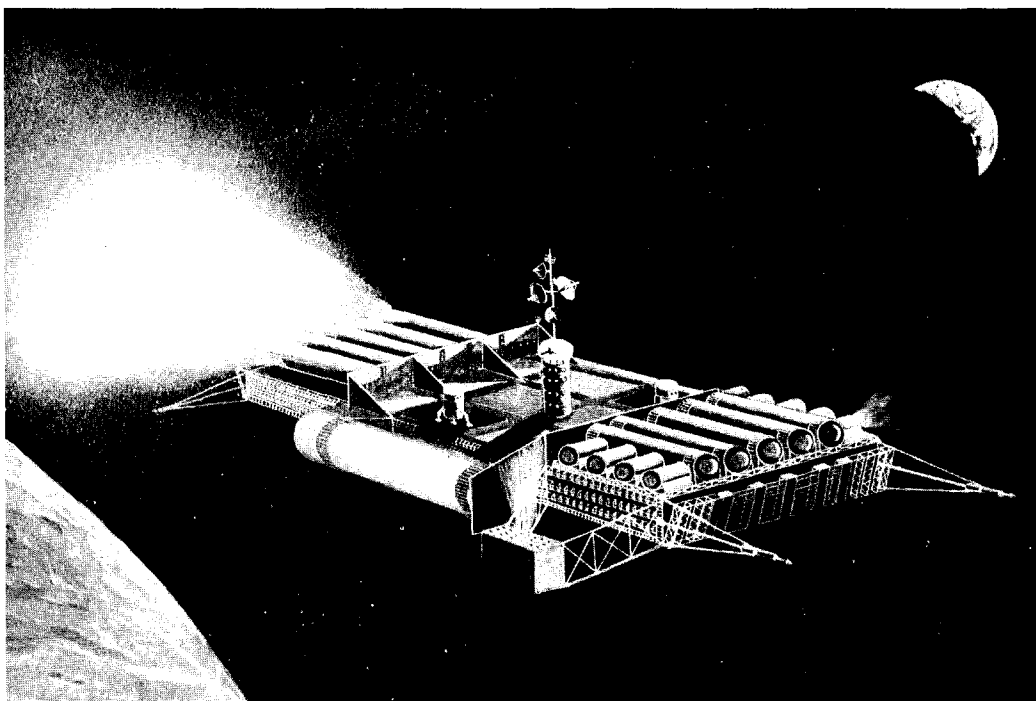
For those who can’t wait, Steen hinted that people with long necks or those with a long board and some persistence can catch a glimpse, whenever they wish, of the capricious Kokopelli and friends, eternally cavorting on the walls of their protected cave.

—JJM

*Petroglyphs cover the walls of Cave Kiva. The spotted animals may be jaguars, done in the Mortandad style of kiva art.*

**"If we are reasonable and if we want to survive,  
then yes—we have to go out into space."**

# THE LOST DECADE



*Space transporter concept: materials are loaded into carrier canisters.  
Illustration by Krafft Ehricke*

Krafft A. Ehricke has dreamt of rocket developments and the industrialization of space for 40 years. Many of his dreams are now history; what fates await his other visions remain to be seen.

"Space has nothing to do with man, but man has to do with space," Ehricke has said. We have lost a decade in that quest, he added.

Ehricke, a LASL colloquium speaker, talked at length with The Atom about his ideas. He founded and is now president of Space Global Co. of La Jolla, Calif. Ehricke has been involved with many technological development projects. He participated in the German V-2 rocket program during WW II at Pennemünde. In the U.S. he later worked on ramjets, the Air Force Dynasoar Project, the first ICBM Atlas, the Centaur and on advanced concepts for the National Aviation and Space Administration.

He has also pursued the human aspects of space colonization and industrialization, often illustrating his ideas with his original artwork. He believes people will eventually live in space, both to assist global economic growth and as a new cycle in human existence.

**Atom:** You have said we lost a decade not only in terms of the space program but in nuclear research as well.

**Ehricke:** Some of the physicists here came to me after the colloquium and said, "We haven't lost 10 years, we've lost 20." There's much that's gotten lost. The graphite block reactor, the high temperature gas reactor, the breeder reactor. The French are now building nuclear power stations to the tune of three to four per year. The Russians are doing the same thing; in fact, the Soviet press made a point: "The West is so confused about nuclear power, they don't move. We know that nuclear power is important; it's our advantage. And we have the resolve to build stations and break economically more into a state of evenness with them. In armament we already are." So they see a chance in the nuclear area. I'm personally so very bitter to hear this country and some others in the Western world downgrade nuclear energy, but they have not a word to say about the buildup of nuclear plants in eastern countries.

**Atom:** Do you believe the waste part of the nuclear cycle is the Achilles heel of nuclear power?

**Ehrlicke:** There are three things that scare people. Number one is plutonium-239, but you could breed thorium-232 and get uranium-233 as fuel instead, but our government unfortunately has not seen it necessary to really push it. Point two is the safety of reactors. It absolutely amazes me that in a country as big as this and with so many remote areas still available that we are not building nuclear parks somewhere. A little irregularity (and that's what Three Mile Island was, not an apocalypse) would not have caused a ripple then. Of course, I'm against building a plant on an active fault; that's silly. Point three is the waste. Nuclear energy is extremely benign environmentally because there are no emissions, no gases, until you come to the subject of waste. We do have technologies that can remove 99.9 percent or better of the uranium and plutonium from the spent fuel. What's left are the other long-term actinides. After about 1,000 years of storage most of the nasty fission products have decayed. After that the actinides, with relatively low radioactivity, may last up to 500,000 years. Their level eventually approaches that of a natural uranium deposit, which contains about 0.2 percent uranium in the rock. So about 0.4 percent of the total fuel mass in a reactor gives you trouble. That you could easily dilute in a glass matrix as oxides, put into a space shuttle, and launch into an orbit between Venus and Earth, or into orbit for Jupiter, and have that planet throw it entirely out of the solar system. While I am not hysterical about this waste, I feel there are places on Earth outside the biosphere, in the basalt layers of the ocean rocks, in salt domes, or in space, that to me appear safe enough.

**Atom:** What's the alternative to nuclear power development if it is stalemated?

**Ehrlicke:** I think the alternative is going to be, excuse the expression, one hell of an energy gap. Unemployment. Reduction in the quality of life. Pressure on the environment. The burden is going to be on the poor. There will be continued dependence on foreign oil, confrontations, military action to safeguard the Middle East. In 1924 Germany produced the first gasoline from coal and in 1944 produced tens of millions of gallons of gasoline. At the end of the war the Allies forbade continuation of this technology. What President Carter now wants to do with



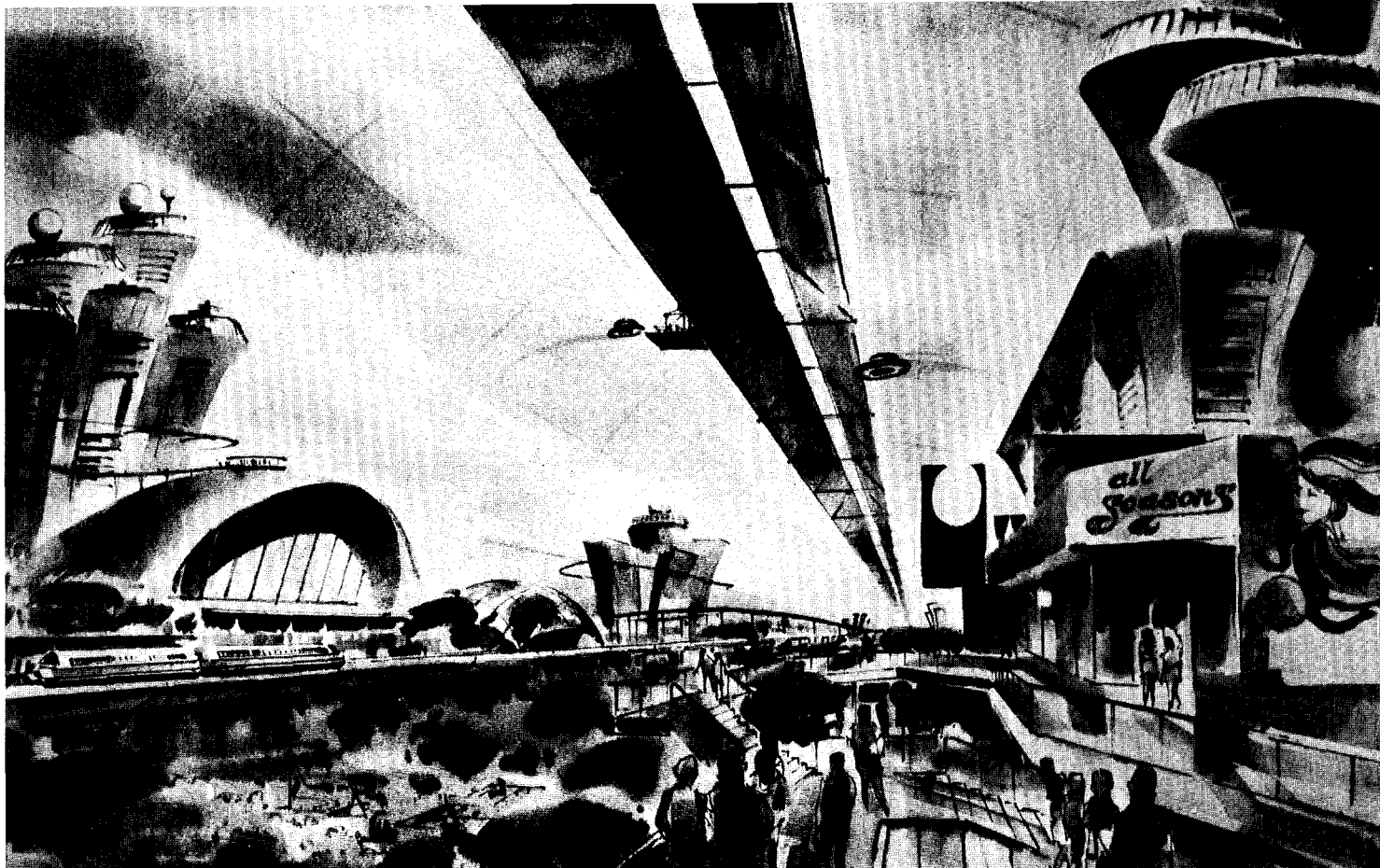
*Krafft Ehrlicke dreams dreams of tomorrow while remaining open-eyed about today.  
Photo by LeRoy N. Sanchez*

coal, I think, is right, but we should have done it a long time ago. Unfortunately, if you want to do it economically, you have to do it in the western areas more than the eastern U.S., but the social factor involves an influx of engineers and miners. There are environmental objections and limited water supplies. The reasonable thing is to get heat for liquefaction from high temperature nuclear reactors, not from coal.

**Atom:** How did we lose the 10 years in space development, and what will the space shuttle do for us now?

**Ehrlicke:** We lost the decade because we did not allow the lunar program to seek its natural continuation in a space station program. Very reluctantly, and against much resistance, the Skylab at least was permitted. But instead of a long-term space station program which would have led by 1973 to a supply ship using perhaps Gemini capsules and by

**"There are three things that scare people: plutonium-239, the safety of reactors, and waste."**



*Impression of domed-space colony, perhaps on the moon, with buildings and greenery creating a pleasant interior atmosphere.*

1976 to a second Skylab, no space station was to be permanently inhabited. In the Apollo-Soyuz program it was the U.S. which provided 90 percent of the work. The Soviets just provided the Soyuz. We had the docking adaptor and the launch vehicle. Before you can get returns from spacebound manufacturing or energy production you need a development period. That could have been done in the 1970s, and the space shuttle could have been put to work for paying activities, almost immediately after it became operational. Limits to growth, anti-technology movements, and the stated social irrelevance of the space program made it virtually impossible for Congress to allocate the relatively few billion dollars that it would have cost for the second Skylab. Unfortunately, in the 1970s the American people didn't have the resolve or the insight or the understanding of space industrialization.

**Atom:** What are the prospects of this changing?

**Ehrlicke:** Gradually it sank in that space industrialization does look promising after all. In 1975, all of a sudden, it was "discovered." Now you

can't talk of anything else, but we lost the decade. The shuttle has run into problems which delayed its launchings. But the big bright spot in the overall picture is still the shuttle. It is a transportation system that allows us routinely, and I hope at a future reduced cost, to get into space. But we also need money for immediate energy projects now, and we have been neglecting our industrial investments, making it harder for free market forces to operate. I'm beginning to look more toward the military. They have very urgent tasks for the shuttle in connection with our strengths in defense, and I hope this helps keep the shuttle rolling even if the space industrialization program might possibly suffer under budgetary limitations. The shuttle is our way out, after all. I do not see the space program going into an easier time, because the shuttle has to operate for years in the civilian area and only consuming money—bringing nothing—because of the lost decade.

**Atom:** You've said that man will not stay Earthbound, that a new species will arise in a space environment, that biological and social changes will occur. How inevitable is your forecast?

**"To assume people will go into space and stay little Earthmen, with little houses, picket fences and simulated mountains and brooks seems to be terrestrial chauvinism."**

**Ehricke:** It is not inevitable. I don't happen to believe in someone who takes care of us up there, no matter how silly and stupid we are. If we want to deal ourselves out of a tremendous future, we are perfectly free to do so. If we are reasonable, however, and if we want to survive, then yes—we have to go out into space. Then we will experience, let's say in an extra-terrestrial environment like that of the moon under one-sixth of the Earth's gravitational field, what I call an "anthropological divergence." I don't mean people will become green or grow three eyes or get another arm. The divergence is typically human; the species evolution was typically biological. Even on Earth you have deviations in skin color, bone structure and civilizations. It is naive to believe we can live on the moon and stay exactly as terrestrial humans. The human body is a chemical machine and must be in equilibrium with its environment, so our bone structure and fluid composition are bound to change.

I'm talking about the state of advanced industrialization where people are spending growing portions of their lives on the moon, being eventually born on the moon, and

growing up on the moon. If you would look at such a person closely, he or she might be smaller, have lighter bone structure, perhaps have differences in blood composition. You would also find immunological differences because new bacterial and viral strains will evolve in these extra-terrestrial environments. On Earth, we're teeming with all sorts of terrible microbes and diseases, but we've built up the antibodies against them.

There are some interesting consequences for Selenopolis, my proposed lunar settlement. The Selenian may want to "experience" Earth holographically—the forests, snow-capped mountains, ocean beaches. But he or she may want such an experience in the safety and comfort of the one-sixth gravitational environment to which lunar inhabitants are immunologically fit.

One thing very fundamental is that on Earth, the biosphere was first and man second. Out there, man will be first, and his created biosphere will be second. Man now has to become the creator of what is provided on Earth free. And what is provided free is always misused, not recognized or valued. We were born with a silver spoon in our mouths and we behave

accordingly. This doesn't mean they'll have no conflicts up there, but they may look at this planet as fascinating and unbelievably cruel. Maybe there might come a time to limit, in space, the people who are working only on behalf of Earth. Because they might carry their hatreds, their prejudices, their historical distortions that the endless war of 500,000 years or more has frozen into their being, like a magnetic field is frozen into a solar wind.

To assume people will go into space and stay little Earthmen, with little houses, picket fences and simulated mountains and brooks seems to be terrestrial chauvinism. We can't now imagine that anything could be different from us. A completely different creature will not arise, but there would be immunological differences, physical differences, aesthetic differences, and there will be philosophic differences because man now has to be the all-out creator of worlds. And he does no longer have what I call a biological silver spoon in his mouth. He's got to do it himself. And boy, does that sober you up in a hurry!

—JLP

# Years Ago

## 30

### Safety Record Set

Los Alamos Scientific Laboratory employees have set a new safety record—more than a million staff hours without a single disabling industrial injury. This record, extending over 75 days, covers the longest period in the Lab's history in which no accidents have been incurred.

### Speculations on open city

The Atomic Energy Commission has decided to pull the government out of the municipal affairs of Hanford, Washington; Oak Ridge, Tennessee; and Los Alamos. Residential and business properties will probably be sold to private citizens, though such a move will not occur for at least several years. Speculation is high among residents and concessionaires about the possible influx of curiosity seekers and competitive businesses when Los Alamos becomes an open city.

### Student boom

The fastest growing school population in the state is in Los Alamos County. County school figures for the 1949-1950 school year showed 1,456 students, a jump of 516 over the previous year. And school officials are predicting another increase of 35-40 percent for the coming year.

## 20

### Building boom

A Santa Fe architect/engineering firm has announced that 52 new two-bedroom dwellings will be constructed in Los Alamos. They include 20 single houses, 20 units in 10 duplexes and 3 "quad" apartment buildings. Construction is expected to be completed in seven months.

The increasing White Rock population is resulting in new businesses springing up there. The Los Alamos Community Center

Cafeteria opened a cafeteria in White Rock, and Spier's Department Store is planning to open a White Rock branch. Three dormitories now house 100 people in Los Alamos' satellite community; two more will be completed soon.

### Cheaper in Los Alamos

A Bureau of Labor survey compared the cost of living in Los Alamos with four major cities. Results showed that it would cost more to live in a comparable manner in Los Angeles, Chicago or New York than in the "Atomic City." Denver proved to be a little easier on the pocketbook than our city. Although shoppers in Los Alamos pay more for food than those in the other cities surveyed, residents here pay substantially less for housing.

## 10

### Bradbury receives Fermi Award

Norris E. Bradbury, Director of the Laboratory, received the Atomic Energy Commission's coveted Enrico Fermi Award for 1970. The award includes \$25,000, a citation and gold medal. Bradbury was cited for "his inspiring leadership and superb direction" of the Laboratory for more than 25 years, as well as for his contributions to national security and peacetime applications of atomic energy. Bradbury was the fourteenth recipient of the award.

### Rover Program

CMB-1 analysts use a whole element counter to measure uranium-235 in fuel elements for the Rover program. Designed and constructed by CMB-7, the apparatus measures the total flux of 186-keV gamma rays given off by the U-235. In 10 seconds, less time than it takes to put the fuel element in the apparatus and take it out, CMB analysts can measure the amount of U-235 in the element within three tenths of one percent standard deviation.

*Taken from files of  
Los Alamos News, LASL Community News,  
and The Atom.*

## Among Our Visitors

DOE officials got to test drive LASL's hydrogen-powered Buick while visiting the Laboratory. Here, looking under the hood, Walt Stewart of P-10 points out engine modifications to Maj. General William Hoover, USAF, Director of Military Applications (left), and Duane Sewell, Assistant Secretary for Defense Programs (third from left), while Gary Granere, Deputy Area Manager, LAAO, looks on.  
*Photo by LeRoy N. Sanchez*



## etc...

Harry C. Hoyt has been named Associate Director for Energy Programs. Since December of 1979, Hoyt served as acting Associate Director for Energy Programs; prior to that he was Assistant to the Director for Policy.

Hoyt is responsible for all Laboratory programs in energy and

# short takes



*Bob Brashear of PUB-2 demonstrates the heat pipe to Los Alamos High School Science Fair winners. Left to right: Brashear, Scott Wilson, Charles Cantrell, David Bunker and Kent Budge. The students toured the Lab, then had a chance to chat with staff members working in the field of the students' science fair projects. Photo by LeRoy N. Sanchez*

energy-related areas, including program development, management and liaison with program sponsors.

George M. Damoulos has been named head of the Personnel Administration Department (PAD). As department head, Damoulos will oversee the efforts of approximately 100 LASL employees who administer the hiring, compensation, training, benefits and equal employment

opportunity compliance needs of the Laboratory.

Damoulos, a former employee of Sandia Laboratories, comes to LASL from Morgantown, West Virginia, where he was Assistant Operation Manager for EG&G's Morgantown facility.

Peter A. Carruthers, who has headed LASL's Theoretical (T) Division since 1973, stepped down

from his position as division leader to devote more of his time to physics research. Division member George Bell became division leader.

Amory B. Lovins spoke at a special colloquium held in May. Lovins is a representative of Friends of the Earth, Inc., a U.S. nonprofit conservation lobbying group, and is also vice-president of the associated FOE Foundation, an educational charity.

An experimental physicist, Lovins has concentrated on energy and resource strategy. He said we must "stop living in sieves and driving petro-pigs."

An advocate of "soft" energy, he believes the soft energy path emphasizes high energy productivity, is cheaper, faster, socially and politically more attractive and offers leverage against proliferation of nuclear weapons.

In a special colloquium during the Oldtimers' Reunion, Brigadier General John H. Dudley (Ret.) recalled the problems and events that led to the establishment of Project Y.

Veteran weapons engineer J.J. Wechsler has been named head of the Design Engineering (WX) Division. Wechsler takes the place of long-time LASL employee Eugene Eyster, who has led the division since its formation eight years ago. Formerly, Wechsler served as assistant division leader in WX.

## patents

Patent 4,183,671, "Interferometer for the Measurement of Plasma Density," was awarded to Abram R. Jacobson of CTR-2.

Patent 4,189,652, "Beam Splitter Coupled CDSE Optical Parametric Oscillator," was awarded to Nicholas J. Levinos and George P. Arnold, both of AP-2.

Patent 4,189,685, "Self-Protecting Transistor Oscillator for Treating Animal Tissues," was awarded to James D. Doss of MP-3.

Patent 4,189,686, "Combination Free Electron and Gaseous Laser," was awarded to Charles A. Brau and Stephen D. Rockwood, both of AP-2, and William E. Stein of AT-1.

## errata/addenda

Cover photo of the May/June history issue of The Atom was by LeRoy Sanchez.

